Tappi

HE JOURNAL OF THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

MAY 1960

VOLUME 43 • NUMBER 5

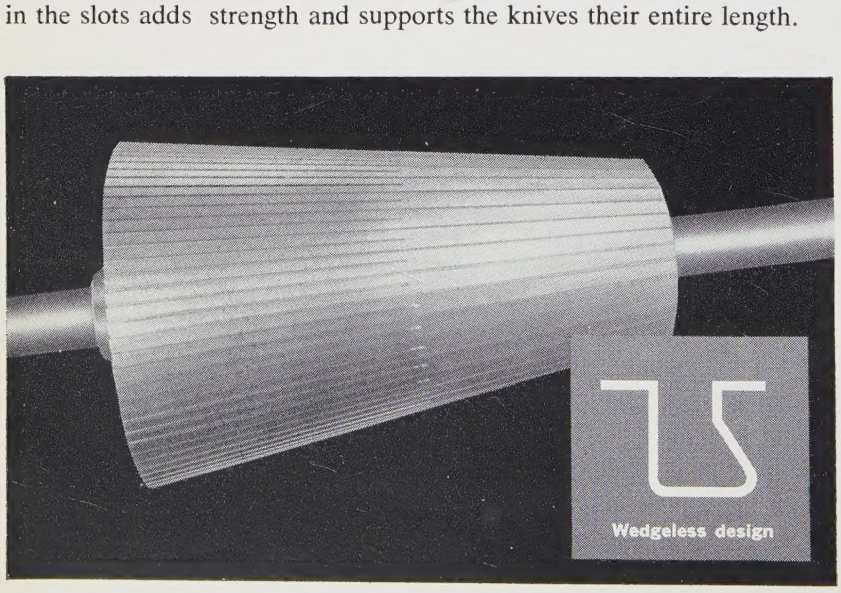
ONLY EMERSON WEDGELESS PLUGS CAN PASS THIS TEST

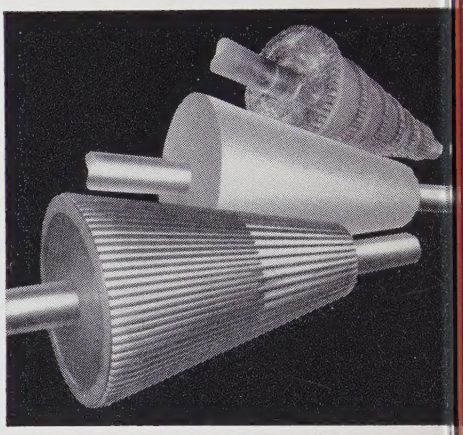
- because only Emerson Plugs have these design advantages!

Before You Buy Another Jordan Plug Check the Answers to these Questions

Question	Emerson Wedgeless Plugs	Other Plugs
Are plugs available in stainless steel?	YES	NO
Are plugs easy to strip and fill because of bandless construction and only one knife to a slot?	YES	NO
Can a full range of knives — both single and duplex — be used interchangeably in the same plug?	YES	NO
Does the design provide impact cushions between the base of the knives and the bottom of the slots?	YES	NO
Is there ¾″ of wear depth available on all knives for long periods of Jordaning?	YES	NO
Can used plugs be jacketed with stainless steel?	YES	NO
Do bars have the advantage of Microlyzing based upon 40 years experience in custom heat treating?	YES	NO

These exclusive features are found *only* in Emerson Wedgeless Plugs. In addition, the unique design of Emerson Plugs gives you precision milled, equally-spaced slots so that when the plug is filled, *all* stock gets thorough, uniform treatment over the entire plug surface. Metal-to-metal contact in the slots adds strength and supports the knives their entire length.





Hundreds of mills have gained the advantages of Wedgeless Plug design by having their used plugs jacketed with Stainless Steel through Emerson's patented process.

DURABILITY UNMATCHED

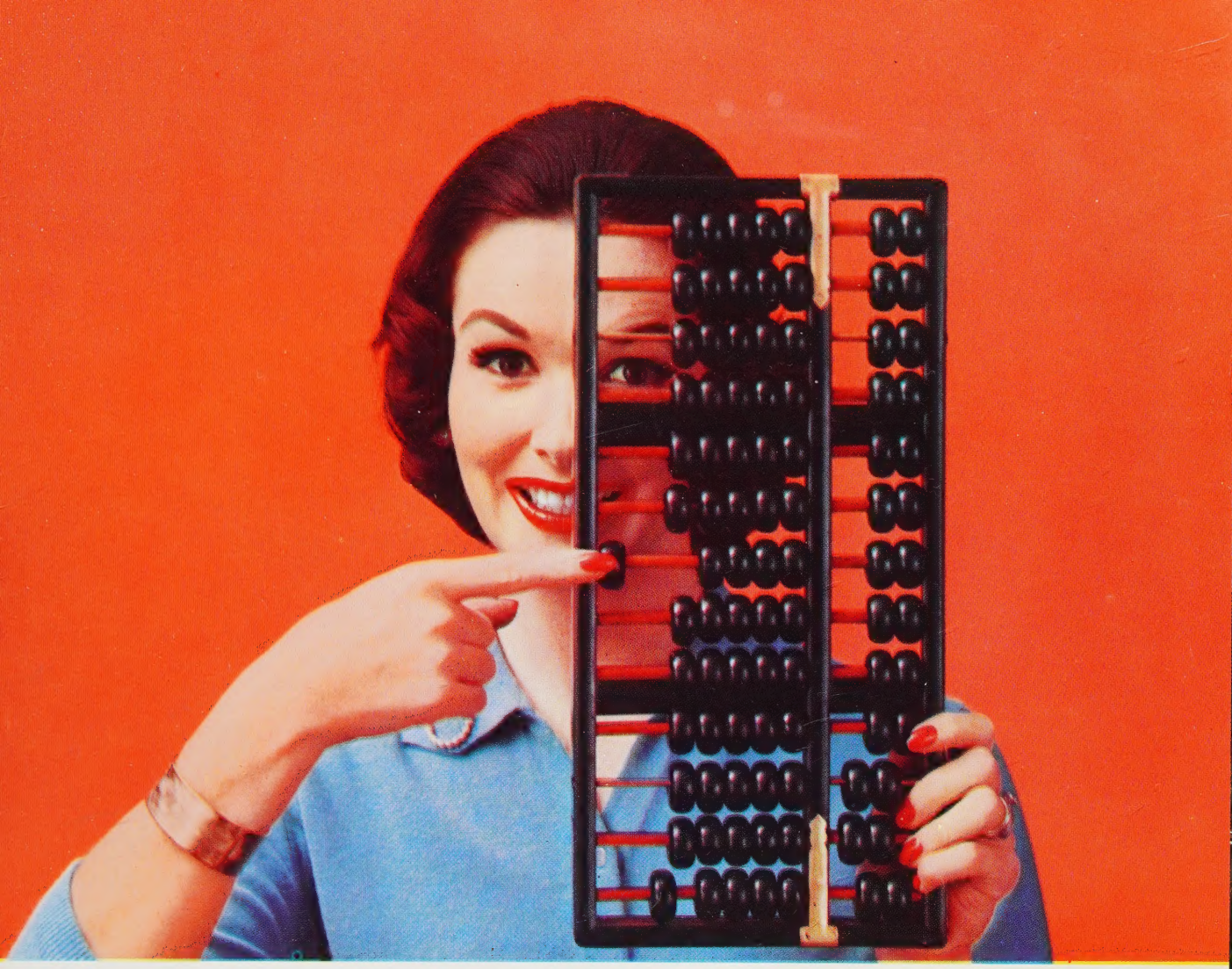
When it comes to wear resistance and durability, try matching the high tensile strength of materials used in Wedgeless Plugs with those of other plugs: Special Stainless Steel — 125,000; Fabricated Steel — 75,000; Cast Iron — 57,500. For additional plug strength, a hammered forged steel shaft is pressed into the Emerson plug body under 60-ton hydraulic pressure. No wonder Emerson Wedgeless Plugs are stronger — more durable and serviceable than any other plugs — and specified by more papermakers.

Over thirty years ago Emerson Wedgeless led the field in Jordan plug design. It still leads today. It has never been equalled. Use Emerson Wedgeless Plugs. Buy the best. Save money, time and trouble. You have a choice of cast or fabricated plugs . . . Stainless Steel Jacket on Cast Steel body . . . Stainless Steel Jacket mounted on your old plug. *And remember, of the hundreds of used plugs jacketed with stainless steel,* ***not one has ever failed in service.*** For full information, write

An exclusive product of

BOLTON EMERSON TRADE MARK

The Emerson Manufacturing Co.
Division of John W. Bolton & Sons, Inc.
Lawrence, Massachusetts



YOU CAN COUNT ON IT—Alpha® Protein improves quality, speeds production, cuts cost

Alpha Protein is a chemically isolated soy protein used as an adhesive in producing today's finest coated papers.

Count on Alpha Protein to provide many advantages—in the mill, and in the product itself. For example, the extra solids possible with Alpha Protein give production increases up to 15% ... allow less drying time ... faster machine speeds ... higher coat weights.

In coated papers, Alpha Protein imparts a true-white brilliance ... improved opacity ... smoother surface ... high resistance to water.

Count on Chemurgy Division as a reliable source where careful control through all manufacturing stages insures uniform quality between shipments.

And finally, count on Chemurgy technical men being anxious to give special attention to *your* problem.

25

YEARS OF CHEMURGY EXPERIENCE

CENTRAL SOYA COMPANY, INC.

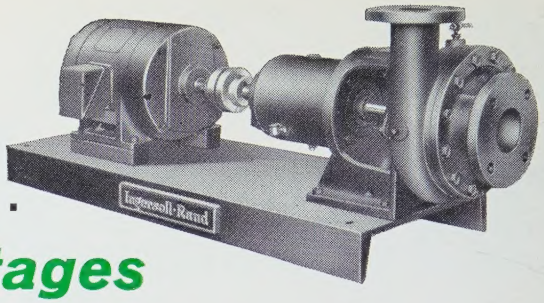
CHEMURGY DIVISION

1825 N. Laramie Avenue · Chicago 39, Illinois

This is a sample of 4-color process lithography on Alpha Protein-processed paper

cradle-mounted pumps for any application . . .

all with these basic advantages



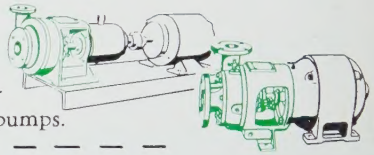
Simplicity of design, rugged construction, careful material selection and expert workmanship enable Ingersoll-Rand cradle-mounted pumps to meet the highest performance standards, year after year, with minimum attention or maintenance.

Built in sizes through 100 horsepower, deliveries range to 3200 gallons per minute, heads to 525 feet. Single or two-stage models available with threaded or flanged intake and discharge connection.

Call on your nearest Ingersoll-Rand pump specialist to help with your liquid-moving problems. There are standard or engineered units to suit any requirements.

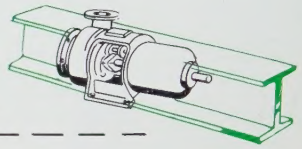
interchangeability

— hydraulically and physically, the pump ends are interchangeable with I-R Motorpumps.



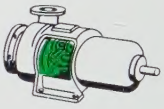
maximum strength

— barrel type construction gives greatest rigidity and perfect alignment.



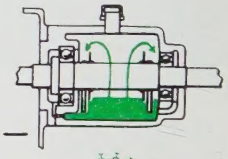
accessibility

— large side openings provide easy access to stuffing box.



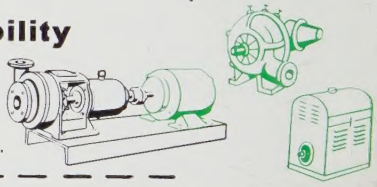
effective bearing lubrication

— ring-lubricated bearings easily handle radial and axial loads.



driver flexibility

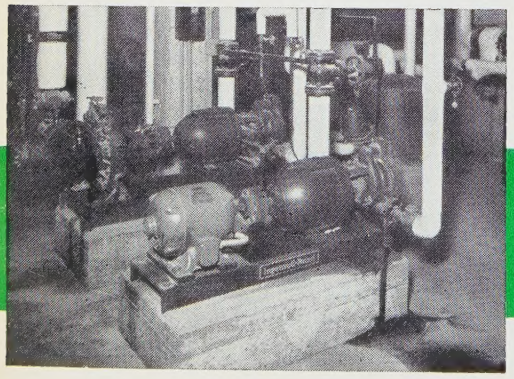
— permits use of motor, turbine, engine or belt drive.



a century **1860 — 1960** *of pump progress*

from the leading manufacturer . . .

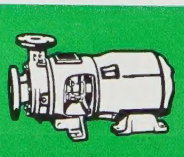
A turbine-driven cradle-mounted pump and a motor-driven standby in a manufacturing plant power house.



Ingersoll-Rand

89A9 11 Broadway, New York 4, N. Y.

OTHER I-R PUMPS AVAILABLE



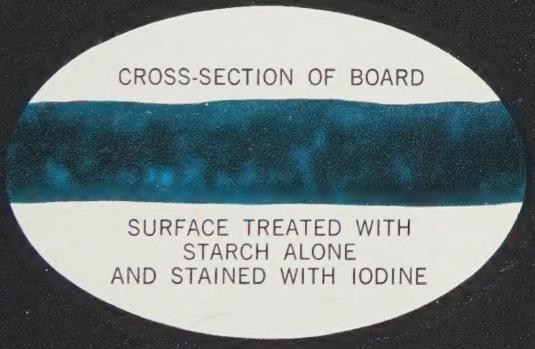
Motorpumps

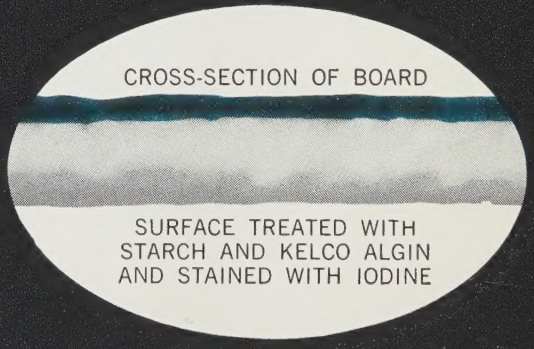
Self-priming pumps

Horizontally split pumps

SEE HOW THESE PHOTO-MICROGRAPHS PROVE...

KELCO ALGIN PRODUCTS CONTROL PENETRATION





These unretouched photographs show greatly magnified **cross-sections** of two pieces of board: One surface sized with starch alone; the other sized with starch and Kelco algin. See how the starch has saturated through the entire paper on which it alone was used. But what a difference when starch is combined with Kelco algin. This combination remains on the surface, proving beyond question that algin **with** starch controls penetration and strike through. For, with unique Kelco colloids you regulate surface density and penetration, precisely and effectively. This is a positive, reliable fact, providing benefits that are well worth test and evaluation in your own operation.

YOURS ON REQUEST: Technical data and assistance by Kelco's highly trained technicians. Without obligation, call or write your nearest Kelco regional office.

Kelco Algin products of KELCO COMPANY

75 Terminal Avenue, Clark, New Jersey • 20 N. Wacker Drive, Chicago 6, Illinois
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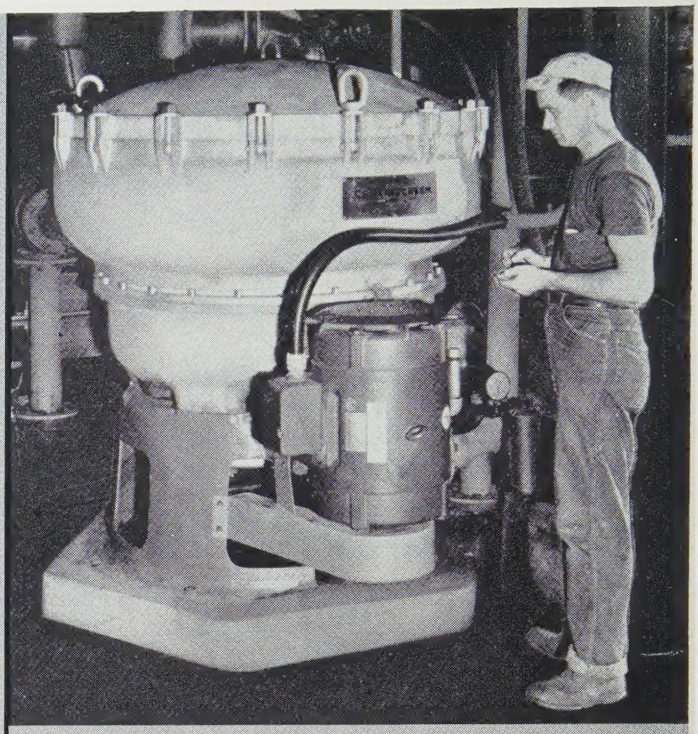
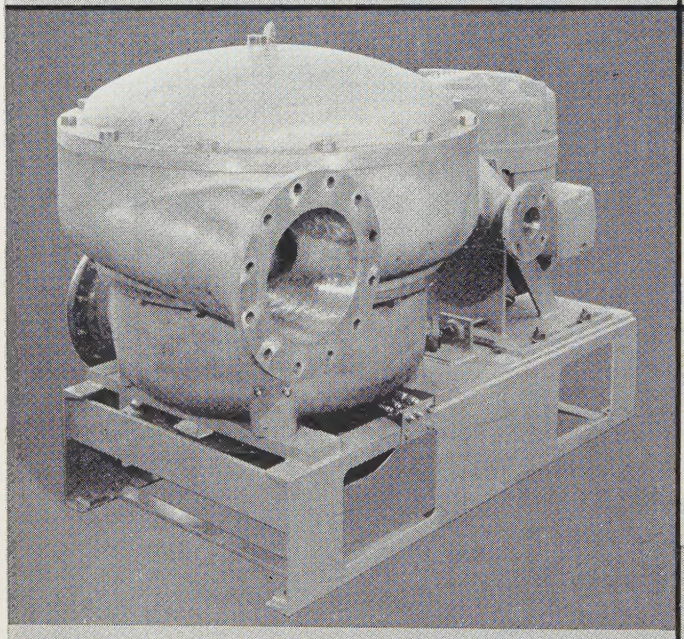
NOW, 3 Sizes of BIRD CENTRISCREENS

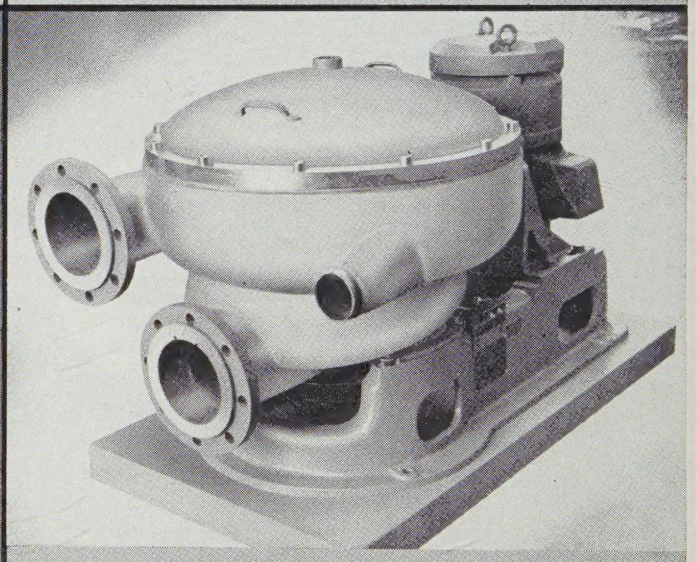
— one of which will do a better screening job on *your* stock and *your* tonnage at *lower screening cost per ton*



The **Model 14** Centriscreen is the pressure screen that has proved so popular, effective and economical ahead of big, high speed paper machines handling all kinds of stock. It handles feeds up to 5600 gpm or more, depending on stock character and consistency.



The **Model 10** Centriscreen is the pressure screen for handling approximately half the volume of the Model 14 — sometimes more on certain kinds and grades.



The new **Model 6** Centriscreen is the pressure screen for small Fourdriniers and for one screen per mold on cylinder machines. Only 30 inches high and 34 inches wide it delivers up to 1200 gpm. It possesses the superb dirt and shive removal efficiency and exceptional operating and maintenance economy of the larger models.

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SOUTH WALPOLE, MASS.

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CANADIAN INGERSOLL-RAND COMPANY, Limited, Montreal

published monthly by the

Technical Association of the Pulp and Paper Industry

at 20th and Northampton Streets
Easton, Pennsylvania

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New York 17, New York

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Tappi is published monthly by the Technical Association of the Pulp and Paper Industry at 20th and Northampton Streets, Easton, Pa. Editorial and advertising offices, 360 Lexington Avenue, New York 17, N. Y. Articles for publication and communications regarding the editorial content of **Tappi** should be addressed to the Editor at the editorial office. Statements and opinions expressed in articles and editorials appearing in **Tappi** are those of the contributors, and the Technical Association of the Pulp and Paper Industry assumes no responsibility for them.

Subscription: U. S. and possessions $10.00; Canadian $11.00; Pan American Union $12.00; Other Foreign $13.00. Single copies to members of TAPPI $1.00; Non members $1.50.

Second-class mail privileges authorized at Easton, Pa. Acceptance for mailing at a special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized January 27, 1949.

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The Technical Articles are in accord with the recommendations of the Division of Pulp, Paper, and Board of the International Union of Pure and Applied Chemistry.

All the publications of the Technical Association of the Pulp and Paper Industry may be obtained from the offices at 360 Lexington Avenue, New York 17, N. Y.

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Eleventh Coating Conference
Edgewater Beach Hotel, Chicago, Ill.
May 23–25, 1960.

Pulp Bleaching Conference
Edgewater Beach Hotel, Chicago, Ill.
June 14–16, 1960.

Fourteenth Alkaline Pulping Conference
Multnomah Hotel, Portland, Ore.
Aug. 22–24, 1960.

Forest Biology Conference
Seattle, Wash.
Aug. 24–27, 1960.

Eleventh Testing Conference
Pantlind Hotel, Grand Rapids, Mich.
Sept. 27–29, 1960.

Tenth Corrugated Containers Conference
Royal York Hotel, Toronto, Canada
Oct. 10–13, 1960.

Fifteenth Plastics-Paper Conference
Hotel Syracuse, Syracuse, N. Y.
Oct. 17–19, 1960.

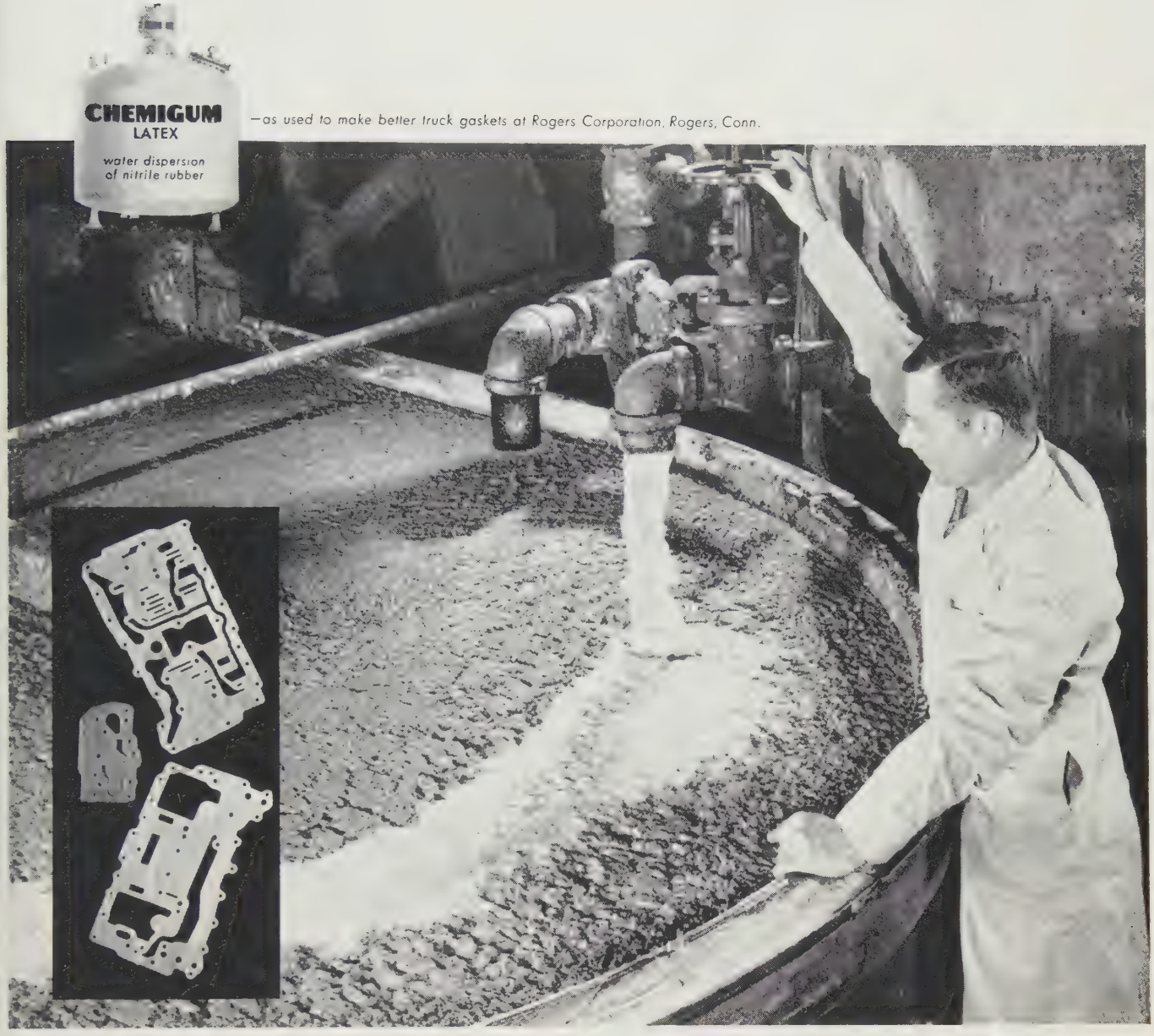
Fifteenth Engineering Conference
Robert Meyer Hotel, Jacksonville, Fla.
Oct. 24–28, 1960.

Please refer to Local Section Activities for the locations and dates of Section meetings

leading manufacturer of
wires for KRAFT PAPERS

APPLETON WIRES
ARE GOOD WIRES

APPLETON WIRE WORKS Corp. PLANTS AT APPLETON, WIS. AND MONTGOMERY, ALA.: INTERNATIONAL WIRE WORKS, MENASHA, WIS. AN AFFILIATED COMPANY



—as used to make better truck gaskets at Rogers Corporation, Rogers, Conn.

How to get the best out of asbestos—with CHEMIGUM LATEX!

The trick was to make a truck transmission gasket having maximum resistance to oil at elevated temperatures plus the strength, compressibility and uniform thickness needed for top sealability.

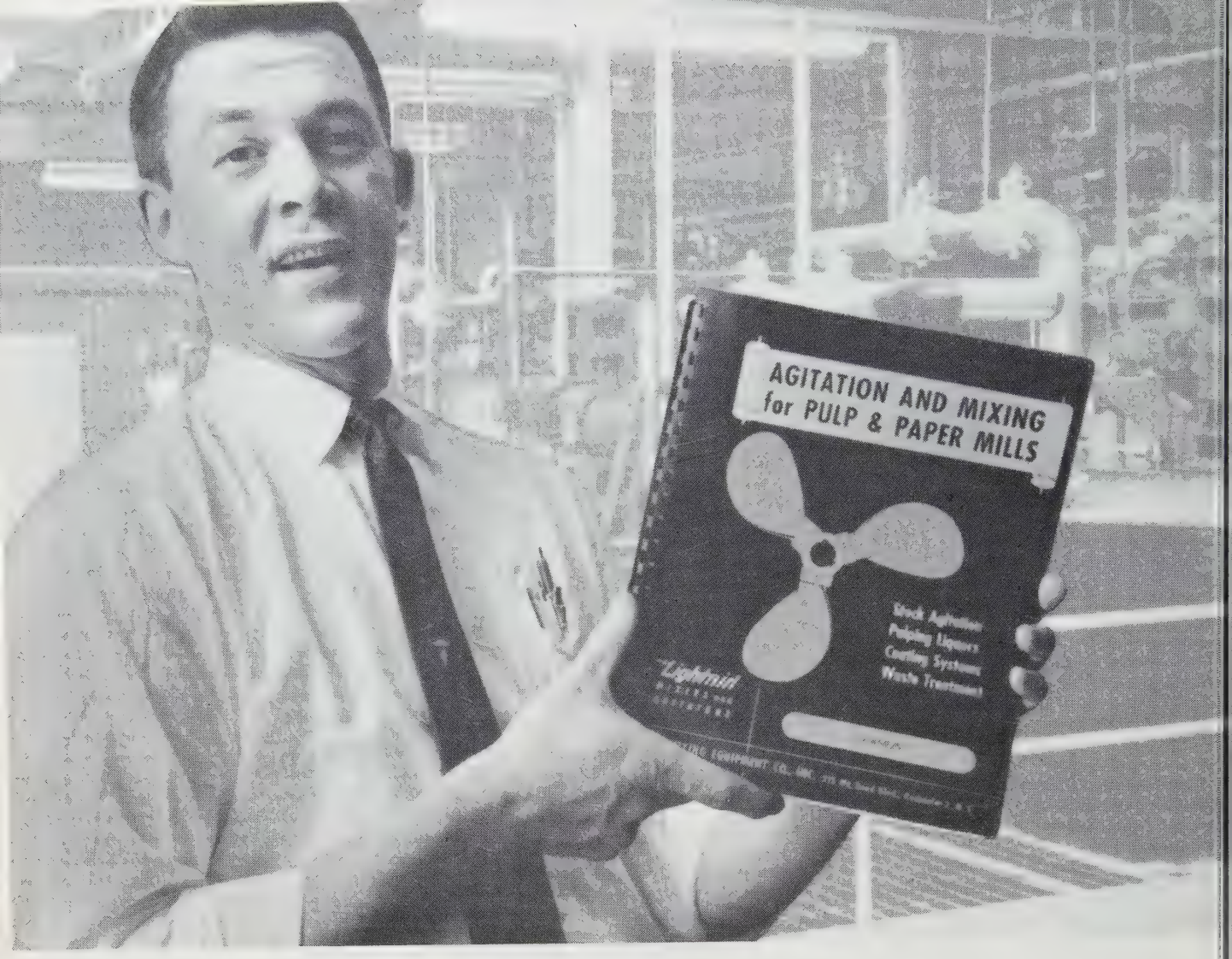
Nothing else worked, until this manufacturer tried fiber-by-fiber saturation of asbestos through the beater addition of CHEMIGUM LATEX.

CHEMIGUM LATEX was chosen for its outstanding oil resistance plus ease and thoroughness of incorporation, mechanical stability and good physical properties. Asbestos was used because of its dimensional stability and freedom from warpage. Beater addition was used to get the most out of both materials and obtain a homogeneous sheet of closely controlled thickness.

How can CHEMIGUM LATEX help your product? Full details, including the latest *Tech Book Bulletins*, are yours by writing Goodyear, Chemical Division, Dept. Q-9432, Akron 16, Ohio.

GOODYEAR
CHEMICAL DIVISION

Chemigum—T. M. The Goodyear Tire & Rubber Company, Akron, Ohio



Getting the results you want from agitated chests and tanks is the subject of this new 112-page manual.

Complete, factual, informative, it is the first book of its kind ever written for pulp and paper engineers. It is based on ten years of unique research into the technology of mixing and agitation in the pulp and paper industry, and on hundreds of mill installations, many of which it describes and illustrates.

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Here is a partial list of the contents

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High-density storage, bleaching, blow pits and blow tanks, couch pits, repulpers.

PULPING LIQUORS. Fluid dynamics: blending, heat transfer, solids suspension, dissolving, gas-liquid operations, liquid-liquid contacting.

Case examples. Green liquor storage, salt cake dissolving, bleach liquors, lime storage, bleach liquor storage, smelt dissolvers, sulfur melters, waste neutralization and oxidation.

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Research and the Paper Industry

DAVID L. LUKE

It is a privilege to be here. I honestly enjoy every opportunity to discuss the broader aspects of research in our industry. I've long had a strong general interest in the subject. I believe firmly that aggressive, continuous, and expanding research is vital to the welfare of our industry and, indeed, to society as a whole.

In these comments I'd like to make three points:

First, forces at work in our industry have always fostered research, with the result that the history of our industry has been a history of successful, even though diversified and apparently sometimes unorganized, research.

Although our industry is a large one, standing fifth among those which go to make up the Nation's economy, it is a highly diversified one. There are almost 500 competing companies in this country alone, and the largest of them accounts for less than 10% of the volume alone. I point to these facts so that it will be understood that as an industry we can employ a large number of scientifically trained people albeit without the spectacular concentration of scientists in some other large industries—and why I said that our research is diversified and, as compared with that carried on by the giants of some industries, apparently—although only apparently—unorganized.

Second, I'd like to discuss my belief that research will play an even larger role in our future than it has done in our past.

Third, I'd like to support the view that our industry offers unexcelled career opportunities for research-oriented persons with good scientific training, as well as for technically trained people who are interested in the practical applications of the fruits of research even more than in research itself.

As to the first point, because our industry has faced a succession of challenging and basic problems over the years, particularly in the field of natural resources—wood and water—as well as changes in the qualities of both pulp and paper demanded by both old and newer markets, we've had to use research almost continuously in seeking solutions. Truth to tell, we've had no choice but to accept the necessity for invention based on scientific investigation.

We're told that paper was invented by the Chinese some 18 centuries ago. But until the latter part of the 19th century, the principal raw material consisted of rags. Toward the latter part of the last century, limited supplies, and increasing costs of rags began to restrict the capacity of the industry to satisfy even then the growing demand. The industry was freed from the economy of the rag-picker only through the development of chemical woodpulp, first produced from sprucewood.

This development was a major milestone in the history of our industry. It made possible low cost pulp. It made possible low cost paper. Low cost paper made national magazines, national advertising, and national markets. This combination as much or more than anything is responsible for the mass production industries on which so much of the strength of this country has been and is based. The development of chemical woodpulp was not only a historical event—it produced, as I've indicated, dramatic results.

Soon, much sooner than anyone expected, the demand for woodpulp outgrew the spruce forests on which chemical woodpulp was originally based. Again the industry needed to find the means of growth beyond the then limited natural resources. In those days pines were weed trees, as were many of the conifers of the Pacific Northwest. These conifers were not only more dense, they were much richer than spruce in coniferous pitches, and all were considered much more difficult to pulp than the spruce on which the industry had been based.

But these conifers were abundant and they were low cost. The cost of harvest in the mild climates in the South and Pacific Northwest was considerably less than the cost of harvesting spruce, which grows only in the more seasonal parts of the world. Research, diversified, and in some cases seemingly unorganized, not only in this country, but in other parts of the world, was responsible for the successful addition of all conifers to our list of raw materials—the natural resources which support our industry. The result of the research which made these low cost conifers available was an enormous addition to the effective supplies. The results really opened a vast new market for papers and boards for utilitarian purposes—innumerable types of packaging, building materials, household papers, and a host of others which serve as intermediates of various manufactured products. The result of the research which made the low cost conifers available to the industry is a market which today is much larger than the traditional market on which the industry was based—that which we call the cultural market, if you'll permit the use of the word cultural to include comic books, as well as telegraph blanks, bill heads, envelopes—as a matter of fact, all means of communication.

Within the past generation the growth of our industry has begun to exceed the availability not only of spruce, but of all conifers. Also the industry is beginning to recognize the great waste of ignoring the balance of nature as it exists in the forest—the balance between soft and hardwoods as Nature grows them. These factors challenge the industry to learn to use hardwoods and again, through research, the industry has gone far to meet the challenge. In so doing it has again increased the effective supplies of raw materials and, at the same time, found further means of resisting cost increase. In these ways, supported by research, it has again strengthened the economic advantage of

David L. Luke, President, West Virginia Pulp & Paper Co., New York, N. Y.

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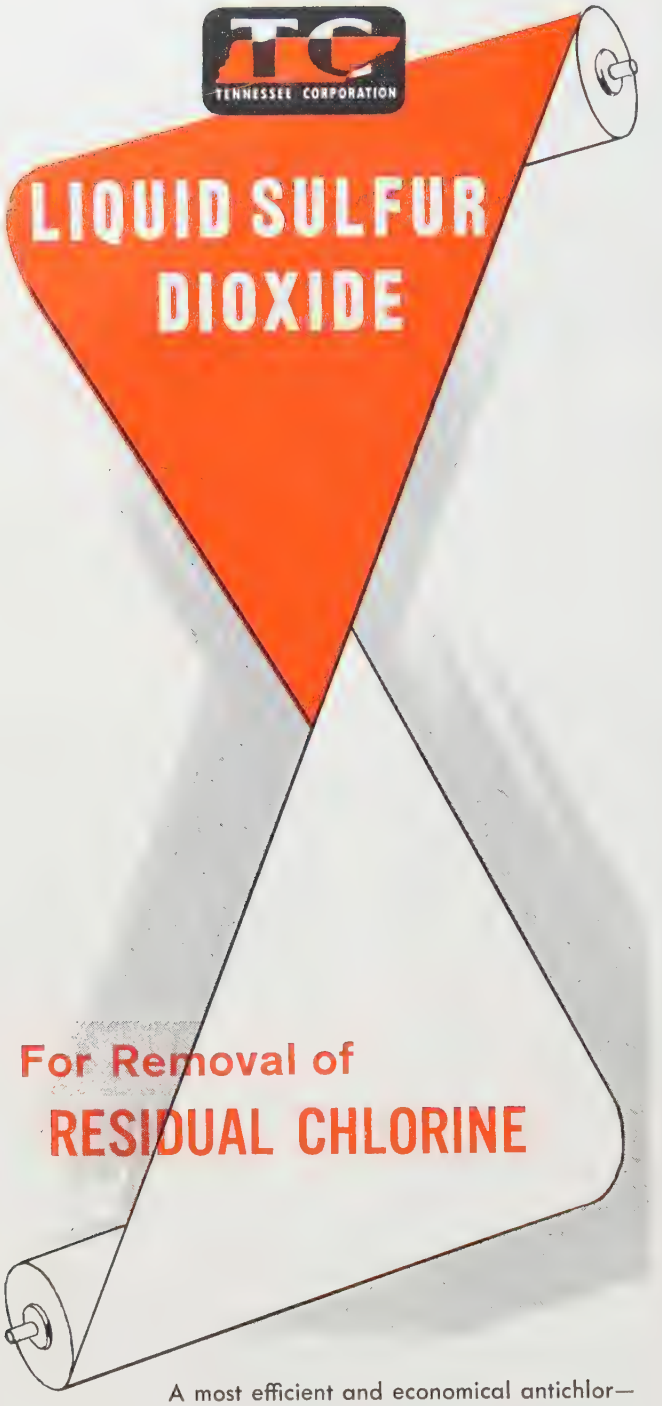

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paper vis-à-vis competing industries such as glass and steel, wood and textiles, and today the foils and the films.

Earlier in my comments I mentioned another natural resource—water. The development of processes which enabled us to substitute a broad range of conifers for spruce, and which now enable us to begin to substitute hard- for softwood, has done more than simply increase our low cost wood supply while protecting our forests from overcutting—it has also done much to adapt the industry to what many farsighted people feel may be our most serious future problem, our most important single natural resource—water. By opening up the use of new species, and with them whole new forest areas, we have been able to draw on many more sources of water.

And more than all this, research has enabled us to minimize the need of the streams to assimilate our pollution. The change of the pulping process from acid to alkaline, which gave us the opportunity to use all the conifers, also gave us the means of contending with the pollution of the cooking process itself. We still have far to go, both in the improvement of our processes and in the treatment of that pollution which at any particular period of time it is impractical to eliminate. But through research we've made much progress. Today we have not only better processes, we also have such means as activated sludge treatment and trickling filters for reducing the damage done by pollution. Through research we've also learned how to relieve the load through conversion of waste into valuable new products such as, for instance, active carbon, tall oil, and terpenes, just to mention a few.

The same forces which have stimulated research in the past, in my judgment, promise to be even stronger influences in the future. Why? Because we shall not only continue to face a quickening succession of challenging problems, to work with a fast-changing technology, and to be staffed with a considerable number of men trained in the scientific disciplines, but because the demands for the products of our industry seem to accelerate rather than stabilize, while at the same time the competition from other industries seems to broaden and grow more intense. Our industry today recognizes more clearly than ever before the great need and, even more important, the vast potential which research holds for our particular areas of opportunity. In our own company we have more than quadrupled our explicit research investment during the past 10 years. In our own company we are projecting continuing increases in research investment, and I'm sure that we don't have much more vision than our competitors.

Let me barely suggest a few of the great future opportunities. First, let's look at the forest. From the standpoint of research, it's almost virgin. In the Southern States where wood grows most rapidly on this continent, we have been accustomed (and we've been studying growth rates for more than 40 years) to an average of perhaps $^1/_3$ cord per acre per year. Our company operates an experimental forest of 20,000 acres, in which we're now growing wood at a rate four times that average. Among other things, we have learned that we can get superior trees by choosing seed from the superior quarter of the forest. Having made

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the first cut, we've attempted another, and we expect to be able to continue to take cuts from the top fraction of the seed orchards and thereby achieve further improvement in seedling quality and so in tree quality. We've learned such simple things as that controlled drainage opens the most fertile soils—and of itself accelerates growth rate. To mention so little by way of illustration is an oversimplification of the findings of the forest researcher, but does indicate that it's possible to breed trees that grow fast just as it's possible to breed horses that go fast. It does indicate that it's possible to do still other things, and to someday show the kind of improvement already shown by the corn or wheat farmer.

The challenge to reduce both stream and air pollution, and the challenge to exploit potential by-products, have stimulated research in these related areas. By changing processes, as well as by more careful and precise design of existing processes, as I've already indicated, we've gone far to minimize both stream and air pollution. However, we've gone only a very small distance toward our goal of developing the by-products of woodpulp. We've only scratched the surface of what can be done. About half the tree consists of cellulose and is used in producing paper, paperboard, rayon, acetate fiber, or such films as cellophane. Except for its fuel value, however, the rest of the tree is largely wasted. Theoretically we can learn to convert the organic chemicals of the waste into valuable intermediates and derivatives. The oils, terpenes, lignins, and aliphatic acids have tremendous unexploited possibilities, as has cellulose itself. If we learn to produce chemical products with the same aggregate value as the pulp we now get from the half of the tree we constructively use, we'll add something like $10 billion per year to the industry's contribution to society in this country alone. And that this can be done is no dream. Some of us in the industry have taken small steps. Others of us are currently taking slightly larger steps. Forty years ago we saw the beginning of the coal tar industry. Twenty years ago we saw the beginnings of petrochemicals. Today, we are on the threshold of a new industry based on wood chemicals.

In the field of papermaking proper, there's great opportunity for the application of disciplined research. In many respects papermaking is still more art than science, and precisely because sufficient research has not been invested to insure adequate control of our processes. The potentialities of new grades of paper, new combinations of paper with foils, films, and plastics, and the possibility of developing products possessing unusual new qualities have no visual limitation. One powerful reason why I'm so confident that we shall exploit these and other opportunities lies in the fact that competition will force us to do so. Paper has made great inroads during the past generation on markets previously occupied by wood and textiles, glass and metal. It has been able to do so because of its amazing versatility and economy, both born of research. New challenges to us from these competitors, from the oil industry and the chemical industry will spur us, I'm sure, to still greater efforts.

While I'm talking about competitors, let me emphasize the fact that competition today is not only the internal kind—one paper company competing with another paper company. The much more serious, much more vigorous competition today is that of industry versus industry, and here it is all too true that it's not just price competition alone that counts—it's the competition from the new commodity, the new technology, the new source of supply, the new type of organization—competition which commands a decisive cost or quality advantage, and which strikes, not at the margins of the profits and the outputs of existing firms, but at their foundations and their very lives. This is the kind of competition which makes me so very certain that research will play an even larger role in our future.

Already implicit in my remarks are some of the stronger reasons why the paper industry offers unexcelled career opportunities for research-oriented persons with good scientific or technical training, as well as for people primarily interested in the application of the fruits of research. The industry has the kinds of processes and the kinds of problems which offer a tremendously rich field for creative effort.

Beyond this let me say only a word about the congenial economic environment found in our industry. Ours is a growth industry. There have been few which have enjoyed a sustained rate of growth as vigorous as ours. Further, unlike steel and other important industries, cyclical fluctuations in ours are mild, partly because of the growth trend which has up to now absorbed much of the cyclical fluctuation, and partly because our products are used up quickly. In consequence, employment in our industry is notably steady. Annual research investments do not fluctuate as they have done in some other industries. Still further we don't mine our raw materials; we do not deplete our supplies of natural resources. In reality we are forest farmers who, as a result of research, are actually and annually increasing our crop of available raw material. This has not always been true, but as a result of research it is true today, and if our projections can be justified, it will be even more true as the years go on.

People trained in the scientific disciplines occupy positions of recognized importance and distinction in our industry. Their rates of compensation are consistent with their importance. They provide us with a large proportion of our principal executives.

Finally, a point which in my judgment is of very great significance is the fact that while ours is a growing industry, there are no giants in it. In relatively smaller organizations, individuals are more significant. The chances are they get more recognition, and certainly they get earlier recognition than if they're a part of one of the vast industrial organizations which make up some of the competing industries.

The importance which our industry attaches to research and to technical training can have no better testimony than our own Institute of Paper Chemistry. I happen to know of none other which has its own private graduate school. Through it we not only train scientists for the future strength of the industry, through it we are also about to begin a coordinated effort in the field of basic and fundamental research which in due course we believe will benefit the entire world.

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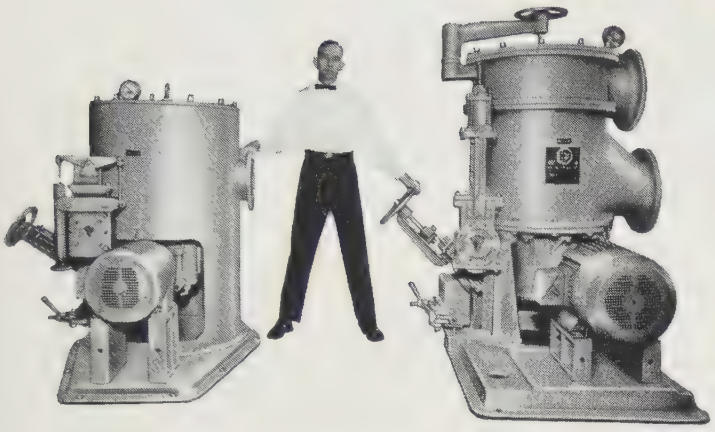

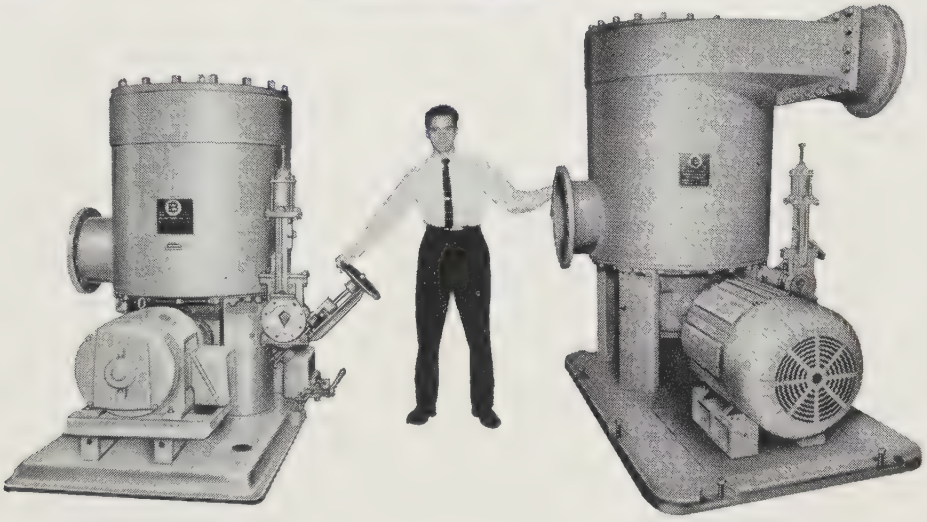

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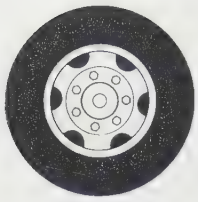

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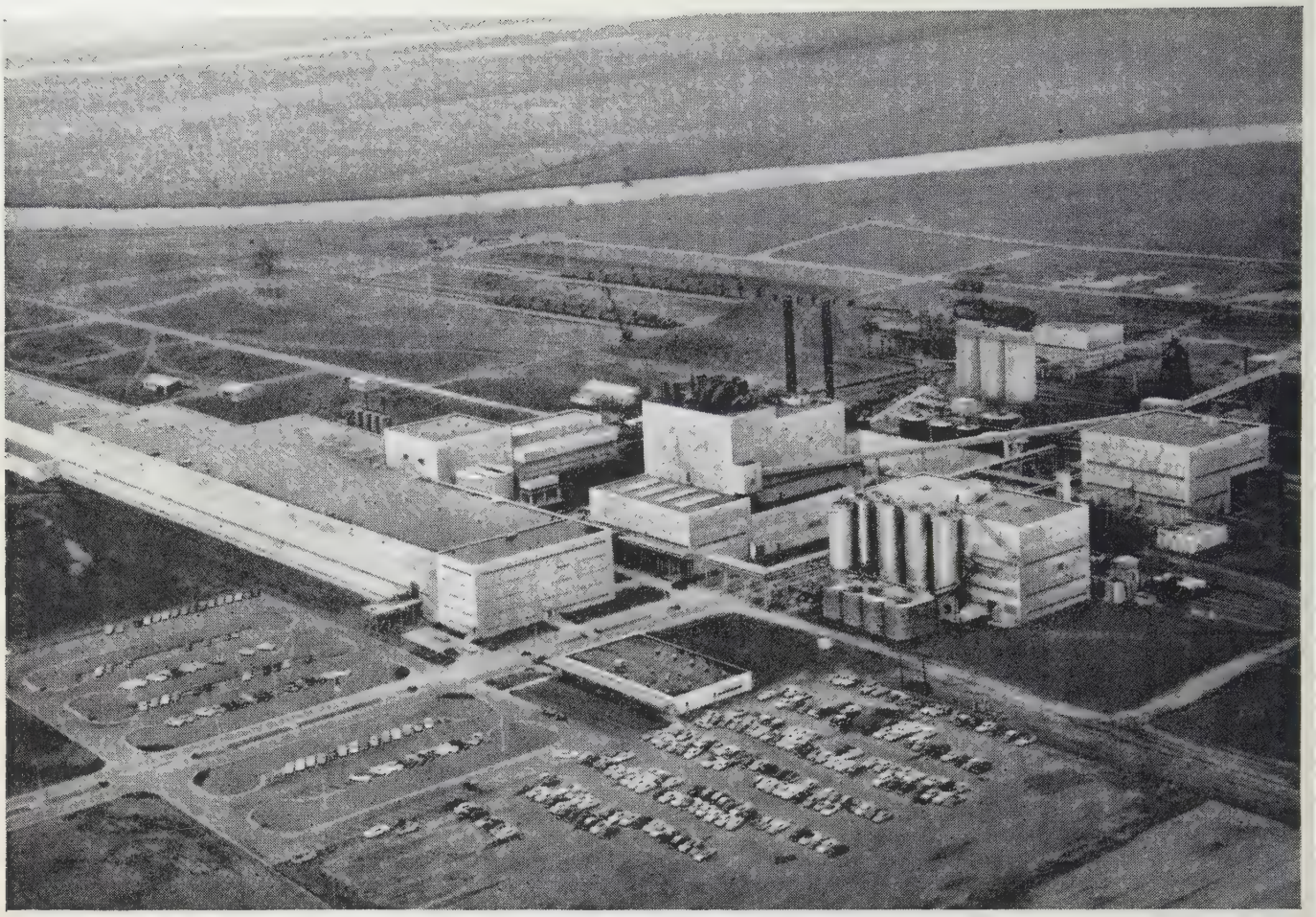

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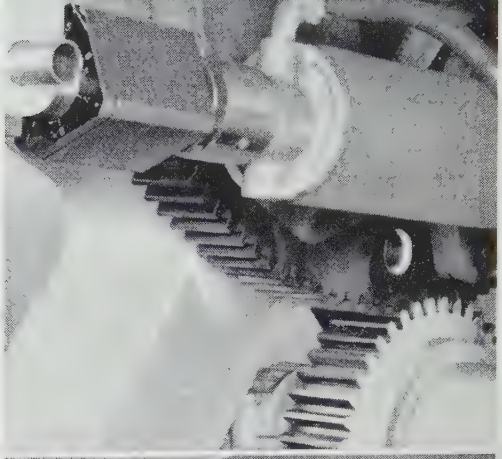

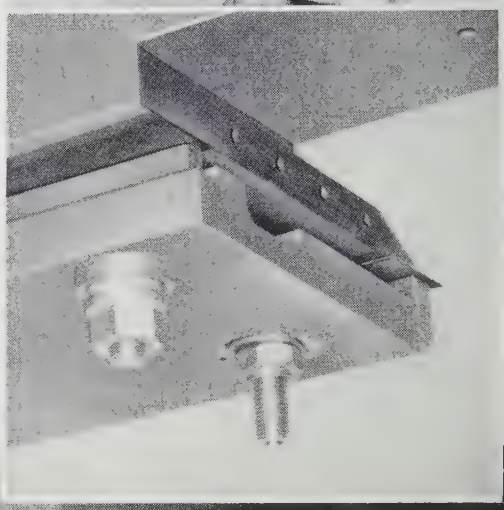

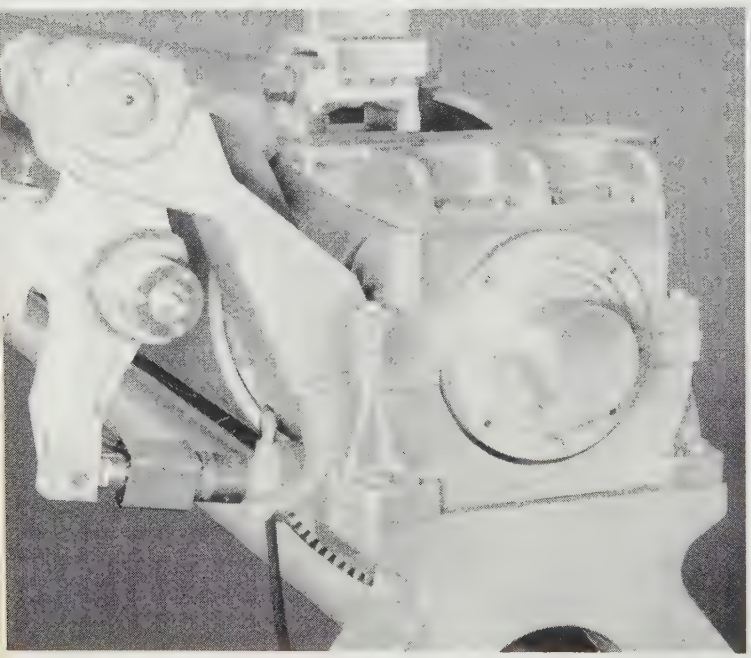

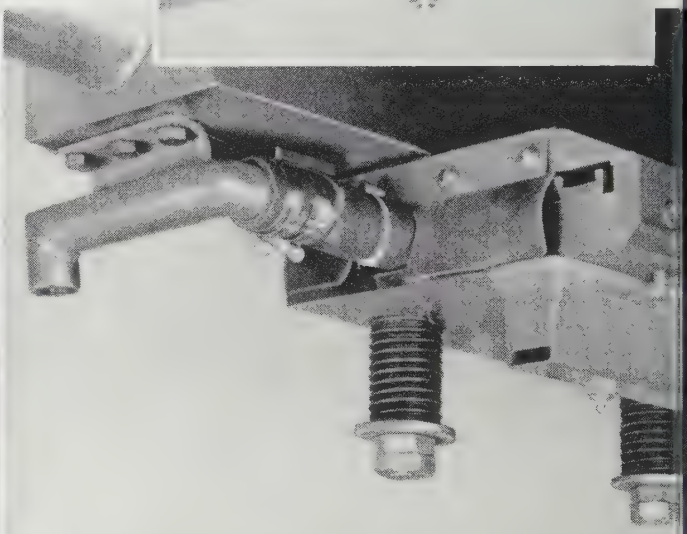

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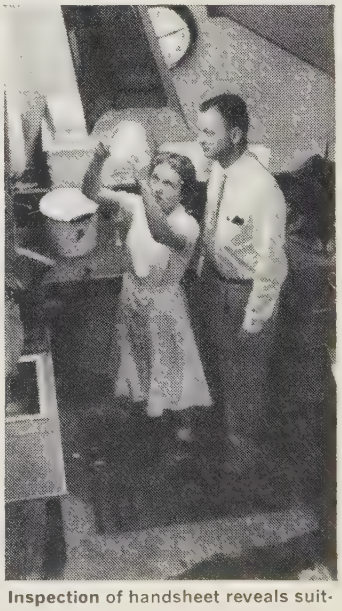
Wood chips (right) are resolved in the digester, then produced into fully bleached pulp (left) for handsheet test.



Inspection of handsheet reveals suitability for physical testing and cleanliness of pulp (presence of foreign dirt or unbleached fiber bundles).

Strategies in Test Planning

CHARLES A. BICKING

A CLASSIC example of failure of test planning, which received a lot of publicity at the time, is that of the *Literary Digest* pre-election poll. A failure in planning of the surveys led eventually to collapse of the magazine. A more fortunate example of survey planning, closer to the interests of industry, was the sampling of mill orders in a bonded abrasives plant to determine the quantities of each type of grinding wheel and each type of specialty product produced. When the first tabulation of results omitted one specialty, honing stones, altogether, the validity of the sampling procedure was questioned. An investigation revealed that a stack of punched cards had been left out of the tabulating run. This stack contained the whole honing stone sample. Its discovery vindicated the planning that had gone into the sampling and gives the company quality control engineers a chuckle when they think of the skepticism with which sampling results had been treated before this episode.

ASK THE RIGHT QUESTIONS

Many less spectacular ways in which failures in planning occur are due to failure to ask the right questions of the physical world. Like the Atlas satellite, an experiment can play back answers only to questions for which it has been structured.

It sometimes appears that we are so sure of what the answer is going to be, that we become careless about the experiment—the query. We may all feel at times that we know what our problems are and that if we could only convince management to give us better instruments, or a new machine, or more help, all our troubles would disappear.

Archibald MacLiesh described this very common feeling in this way: "We know the answers; it is the questions we do not know."

The quality control engineer or statistician knows that industrial problems are difficult and that production workers, supervisory people, engineers, and technical personnel all know more about the problems than the statistician does. In many instances imprecise instrumentation, obsolete equipment, and overloading of men are deterrents to problem solving. One of the things good experiment planning can do is point a finger at these things, if they are really problems, but it is much more important to make most effective use of the resources at hand.

If it were an exact universe that we had to deal with, there might be less of a problem. The old concept of exact science has long been put aside. There is no need to point out that no two units of product are exactly alike. Perhaps we do need a fuller realization, however, that variation is in obedience to natural laws.

CHARLES A. BICKING, The Carborundum Co., Niagara Falls, N. Y.

ANALYZE THE OPERATION

The principles of test planning apply wherever data are gathered, in research and development, and in production situations as well.

Consider a production operation with a high percentage of rejects, sometimes more, sometimes less. We can see that the product is too thick or too thin, warped, or off-color, or that it fails under test, but we tend to look at these as causes, whereas they are only symptoms of process disorder. Moreover, it is extremely difficult to diagnose the true causes simply by looking at the summary in the weekly loss report. It gives us no handle for getting hold of the problems. The failures have to be analyzed; the defects must be tabulated by types so that ultimately the trouble may be traced back to individual lots of raw materials, to particular machines, operators, or periods of time.

Control charts, a designed approach, help to make these breakdowns. Control charts and other simple statistical designs are used to make studies of machine capabilities. We can actually ask and expect to get an answer to the question, "Can the present production process make an acceptable product?"

The next step can then be the substitution of preventative action on the production line for the older practice of sorting out of bad product in an inspection operation. This compares to preventive maintenance, which has proved to be economical. Much effort is spent in many plants putting out fires. Statistical quality control is aimed at detecting the smoke and limiting the blaze.

Quality is the responsibility of manufacturing and control charting and other efforts at control must be carried out by production people. Technical staff personnel should supply expert assistance in setting up procedures (design) and provide an independent assessment of the final result.

Thus it can be seen that quality is not the unique job of any one group but must be the result of teamwork and true cooperation. The S.Q.C. engineer cannot be successful without the cooperation of manufacturing. The team must include line operators, inspectors, supervisors, and engineers in addition to quality control engineers.

APPLY RESOURCES SKILLFULLY

In development work, possibly, though not necessarily, the designs used may be more sophisticated than those used in manufacturing. Exactly the same resources, applied in different ways can have different results. (In the *Literary Digest* debacle, it was not N, the sample size, that was the trouble, but the representativeness of the sample.)

An experiment may or may not be planned to do the things in the following list:

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1. Show inter-relationships.
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4. Cover the area of interest.
5. Describe the complete system.
6. Lead to the next logical step.
7. Be solved numerically.

However, each item of the above list points out a characteristic of good design. Why isn't the way we are doing all right? It may be, in many cases. When differences are very large, no statistics and a minimum of care in planning may suffice. Many experimenters in the past have succeeded by brute force—because they carried on long enough or because enough different things were tried. One approach is to try every bottle on the shelf—but this is too time consuming and expensive. At other times, it may be that we have been satisfied with minor progress. A lot of times, we simply fool ourselves; think of the numerous times that something apparently successful has been disheartening when tried again—or when moved from bench to plant! Also, all our problems are not new, but many have been with us for a long while. We might well question why some of these have not *stayed solved*. We should be appalled by the number of times some of the ground has been turned over.

EMPHASIZE PREPLANNING

Statistical design concentrates on *preplanning* and the carrying out of a plan. It takes cognizance of *compromises* that must be made and of the effect of those compromises—which are sometimes forgotten. It does *not permit changes* in midstream which disrupt or alter the nature of the work (except for reason).

Good test planning calls for some very *elemental disciplines* which should be remembered but which are often overlooked:

1. Clear statement of problem.
   a. Narrows areas of investigation.
   b. Establishes a valid base for conclusions.
2. Collection of basically sound information.
   a. Avoids mistakes.
   b. Minimizes work.
3. Agreement on plan which is adhered to.

Without design, the experimenter is like an explorer without a map or direction-finding instruments.

There is no implication that ordinary experimental work is done without care and skill. What is emphasized is the planning:

1. The physical details of sampling are fully described.
2. The use of sufficiently precise instruments is specified.
3. The exacting control of each step is ensured.
4. Valid treatment of the data is prepared for.

This may, and probably usually does require much more time than is ordinarily taken before work is started. But if one experiment thereby takes the time of two and is successful where two have failed to be conclusive, something has been gained. Or, if twice as much time and care have gone into one experiment which succeeds, it is better than a shorter one which failed and had to be repeated.

It is wasteful to run an experiment if we cannot be sure that there can be an analysis made of the results. We cannot be sure of the analysis unless the data are in shape for statistical treatment. We cannot get out of data, simply by manipulation, what is not in them.

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Microbiological and chemical analyses show the way

Microbiological slime is a constant, persistent enemy to paper mills. In fact, many mill men are resigned to the fact that they will always have a slime condition and that the only way to achieve reasonable control is by constant trial-and-error experimentations with different slimicides. While understandable, this attitude can be costly and uneconomical when measured in terms of slimicide cost, quality variations and down time.

Importance of Scientific Analysis

The point is, effective slime control is possible if the problem is approached with scientific exactness. The source and type of infection must be properly identified. Then a formal program must be developed which details proper slimicide treatment and application, insures proper training of personnel in slime control methods and which insures systematic follow-through and inspection.

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MAKE A SYSTEMATIC APPROACH

We need a systematic scientific approach, instead of the "flash of genius" approach. We should not underestimate technical skill—it is the priceless ingredient—but beg for attention to considerations usually outside the experimenter's skill. The effect of statistical and probabilistic laws of which he may be unaware are just as real and just as important as physical laws. Sometimes the only thing standing in the way of technical accomplishment is the stumbling block of variability. Given the proper attention this stumbling block can be removed.

Why has statistics been overlooked in engineering and scientific training? It has not been overlooked. Particularly in scientific (as contrasted to industrial) experimentation, the theory of errors has had a very important place. Some great discoveries have been fortuitous. Others have resulted from the accumulation of masses of data over long periods of time. Computational work has been tedious. Genius has been described as a capacity for hard work. Much progress has been made by the pure thought process, prior to the experimental phases. This is what must be done: take more time to define the problem, to accumulate background, to state the hypotheses, to foresee outcomes, to look ahead to the comparisons to be made, and to pinpoint effort.

TAKE PAINS WITH TEST ARRANGEMENTS

Some of the details of test planning encompass:

1. Flow sheets of process or experimental steps.
2. A layout of sampling and testing steps: symmetrical blocking of runs and a hierarchical pattern of runs.
3. Data sheets especially prepared for the test.
4. A mathematical model of the problem.
5. A plan of statistical tests to be made.

Although there are many parts of the planning common to all experiments, no grand strategy can be learned which will cover all cases. Each design must suit the problem. There are general types but also many mixtures of types of plan.

This does not mean the designer has any proprietary knowledge or right, but only that no one learns all the tricks overnight. Some industrial statisticians have given a good bit of their careers to it and are still learning. Just as a technical specialty requires constant learning, so does statistics. You can't become a chemist or a ceramist by reading a book or attending a conference. Neither can you become a good Q.C. man that way.

GET A GOOD GRASP OF FUNDAMENTALS

An appreciation of fundamentals should enable the experimenter to collect and arrange information of great help in the designing of experiments.

To the extent that the experimenter can state his problems clearly, provide instrumentation, control laboratory or plant conditions, combine technical skills with statistical skills, demonstrate a capability to act on findings—to just that extent will he be able to step up the pace at which he will move along toward profitable objectives.

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The Impact of Research on the Pulp and Paper Industry

WALTON R. SMITH

RESEARCH is the lifeblood of any industry. I am sure that you have all heard the DuPont story—a company that plows some 5 to 10% of its gross income into research and most of its products today were unheard of 10 to 15 years ago. As for wood-using industries, the wood preservation industry leads the way with 0.41% of its gross income put back in research, and the pulp and paper industry comes second, with 0.30% of its gross income plowed back in research. In general, forest products research is way behind everything else, with only 0.2% put back in research. Considering all types of forest research, the total is much less than 0.1%. But in taking a closer look at your industry, most of the research is in chemical processing, mill equipment, and product development. I don't know what per cent is applied to your raw material before it reaches the pulp mill, but I can guess that it is very small.

On this occasion, I would like to review briefly some of the research efforts important to you in the fields of forest management, wood procurement, processes, and special utilization of by-products. I will discuss research by government, schools, and industry as it may apply to the situation.

FOREST MANAGEMENT RESEARCH

The results of forest management research have made a very definite impact on pulpwood procurement in the past and this impact will continue as these results are put into practice on an ever increasing acreage of forest lands. The development and use of direct seeding, better planting stock, methods of planting and spacing of plantations, early and frequent thinning schedules in natural and planted stands, and properly timed harvests have given us greatly increased yields per acre for the southern pines. We do not have comparable information for our hardwoods, but research is off to a good start.

The increasing use of hardwoods for pulp has given new impetus and direction to hardwood research. Although we are still interested in growing high quality veneer and sawtimber, it is often the market for hardwood pulpwood that makes intensive forest management a paying proposition.

In the bottomland forests in the Mississippi Delta and in the river bottoms of the Southeast we have large acreages of hardwoods that can match or surpass the growth of southern pine. If we are to realize this potential we must develop thinning schedules and cultural measures comparable to those available for southern pine. The preliminary information now on hand indicates that the management needed to increase the yield of veneer and sawtimber will give an even greater increase in the yields of hardwood pulpwood.

Test plantings of selected clones of cottonwood at the Delta Research Center in Mississippi and the Athens branch of the Macon Research Center in Georgia show that on properly selected and prepared sites we can grow large quantities of wood suitable for pulpwood, sawtimber, and veneer. The results of the early tests in Mississippi were encouraging enough that at least one company in the Delta started a modest program of planting cottonwood. Even more important to the pulp industry is the application of good forest management to the natural stands of sweetgum, black gum, and oak. The improvement cuts and thinnings that remove small or defective trees not only improve the future yields of quality timber but also make a large volume of wood available for pulping.

The situation in the upland hardwood forests is much the same. Growth and yield data now available indicate that a properly stocked and managed stand of yellow-poplar, mixed oaks, or pine-hardwoods may have a third or more of the total yield in pulpwood-size trees. The grade yield studies of the upland hardwoods also show that a goodly portion of a sawtimber or veneer tree should be sold as pulpwood. This not only includes the tops but also those logs that will not pay their way through the sawmill. The soils-site studies of pine and upland hardwoods in the Piedmont and mountains will also have an impact on the future supply of wood. The results of these studies, used with growth and yield data, will aid us in matching species with sites to obtain the maximum growth of wood. In essence, they will help us to grow pine on pine land and hardwoods on hardwood land.

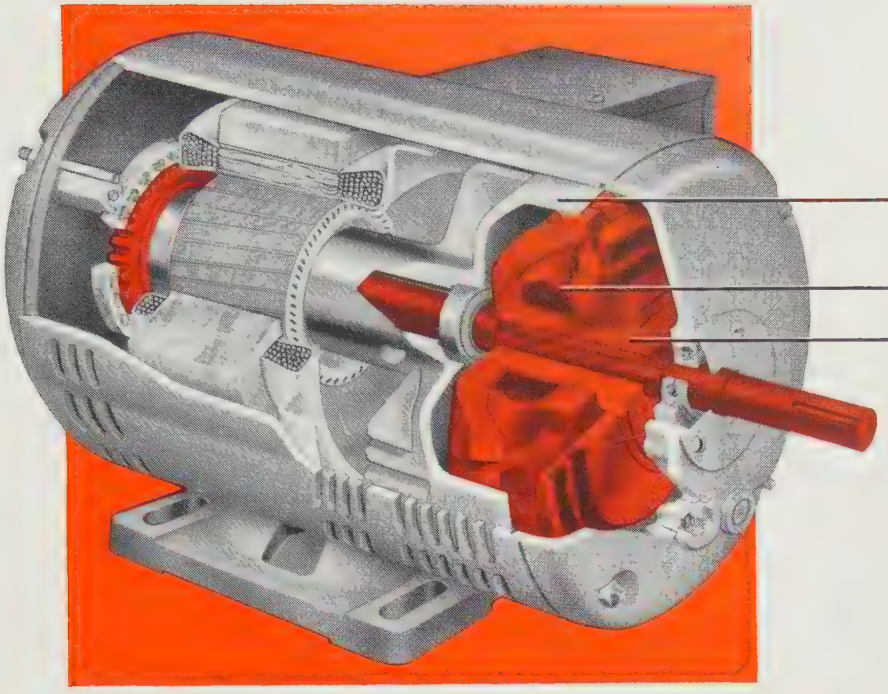
The relatively high level of pine management practiced in portions of the Coastal Plain made good use of past research. Similar gains can be expected elsewhere as we improve our knowledge of stocking levels and thinning schedules. Additional gains will come from the Southwide tree improvement programs. As research selects and breeds improved strains we will be able to increase yields further. By producing fast-growing, disease- and insect-resistant pines we will increase wood yields. By growing wood of a specific quality—high or low specific gravity, maximum cellulose content, or long tracheid length—we may increase pulp yields per acre without an increase of gross wood volume. The differences in pulp yields of "core" or juvenile wood and old wood has been established through research and this knowledge can be used in wood procurement as well as in forest management.

To date, forest management research has increased the volume of wood available for pulping; in the future we also hope to increase the amount of pulp in a given volume of wood.

PROBLEMS IN WOOD PROCUREMENT

Logging or wood procurement is undoubtedly the oldest activity of the wood-using industry. It would appear that we should know all there is to be known

WALTON R. SMITH, Chief, Division of Forest Utilization Research, Southeastern Forest Experiment Station, U. S. Department of Agriculture, Forest Service, Asheville, N. C.



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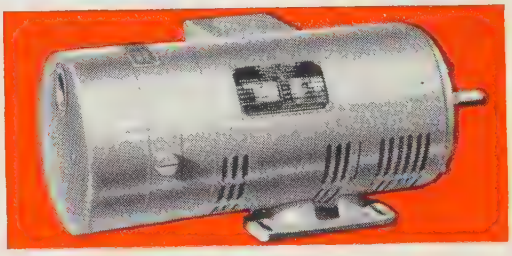

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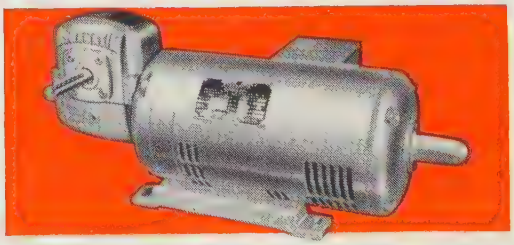

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about this activity, but a little reminiscing will reveal that we have improved this process a hundredfold in the past fifteen years. We have come from the ox-and-yoke logging operation to Tom Bush's mechanical monster in this period of time. A few think we have approached the ultimate, but I believe that the progress during the next 15 years will surpass that which we have experienced in the past fifteen. The average operation today results in a cost of at least 10 dollars a cord to get the wood out of the forests. To this must be added stumpage, freight, and other costs.

What are we doing or can we do today with the equipment available? We believe that woods operations can be greatly improved and costs reduced. We scheduled some research in this field with Lightsey Brothers in South Carolina, but Hurricane Gracie forced a postponement of our plans. We want to take two comparable timber tracts approximately 40 acres each and log one in the conventional manner, keeping complete time records and equipment costs. On the second area we plan to lay out the operation for directional felling, full tree or tree length logging, and mechanized log breakdown at a landing or other location, again keeping complete time and cost records. These are certainly not new ideas because such operations are going on and can be observed, but there is not much in the literature on comparative costs. Further studies are needed on felling techniques and the use of various types of skidding and hauling equipment for different forest conditions.

You are probably aware of the fact that the Federal Forest Research Program has not been financed to conduct equipment research, so our efforts along these lines must be cooperative with industry, taking advantage of existing production equipment and gearing our research efforts to interfere as little as possible with a going logging operation.

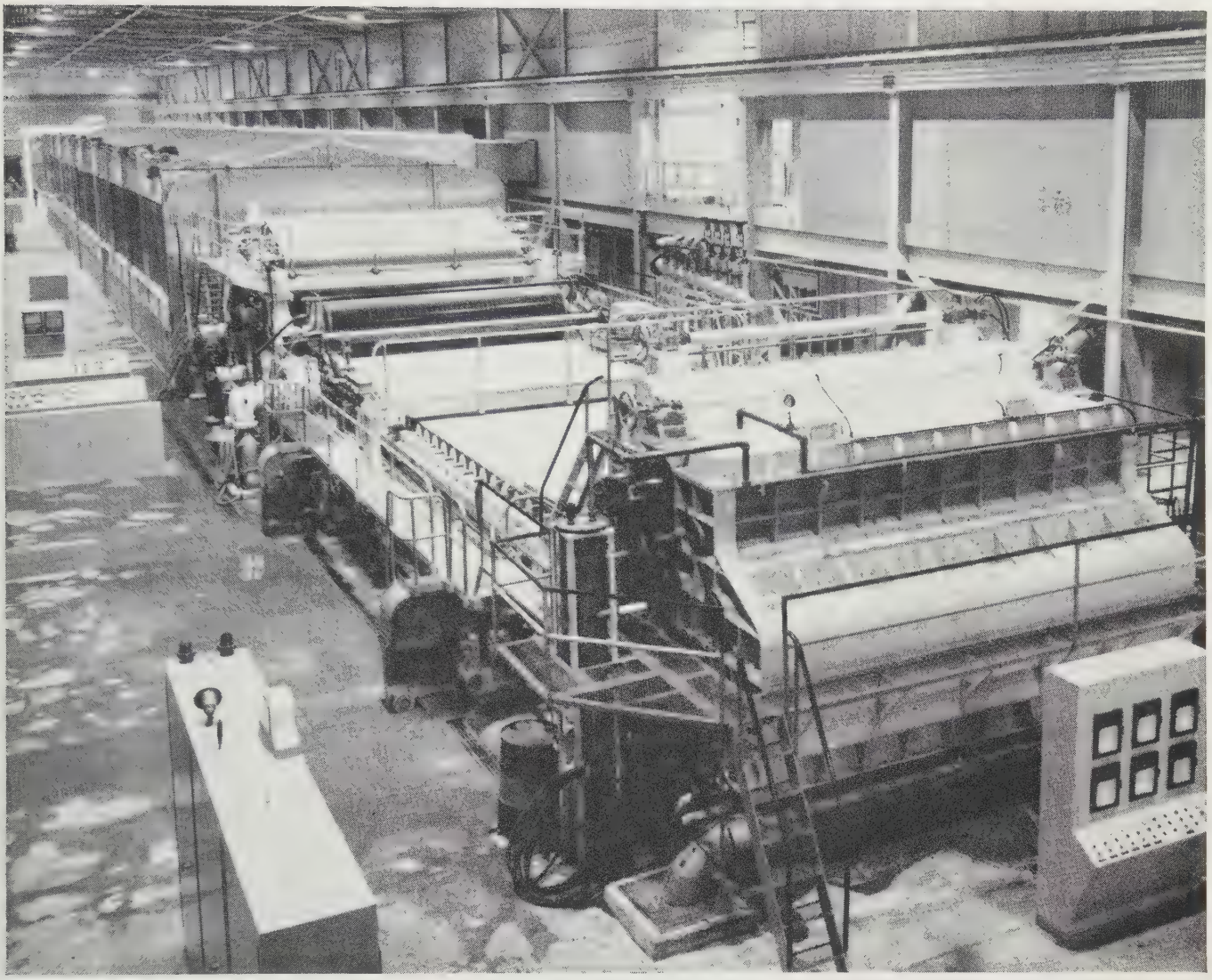
Through the use of log debarkers, slab debarkers, and chippers, southern pulp mills are obtaining an increasing amount of raw material from slabs, edgings, trim, and even sawdust that was formerly unused. We have come a long way in this field but we still have a long way to go. Residue utilization could supply about half of our pulp requirements in the South. This is good for the sawmill industry because it provides almost complete utilization. It is good for the pulp industry because it provides the cream of the tree for pulp use. You are undoubtedly familiar with the research that proves that specific gravity (and hence pulp yield) increases from the pith to the bark and decreases from the stump to the top of the tree. Furthermore the clearest wood is on the outside of the tree. Hence, slab wood makes better pulp and provides higher yields. Anything done to increase this source of raw material is in your favor.

Only recently the use of sparse tooth saws has made it possible to get a sawdust chip big enough for pulp use. J. T. Griffin of Georgia sparked this development about a year ago and now it looks like it is here to stay. These saws work especially well on an operation where there is a constant feed into the saw, such as circular gangs, edgers, etc. They do not work as well with a variable feed speed, as in a small circular headsaw so underpowered that the operator babies the saw through the cut.

We are testing these saws and the pulp produced from the saw chips at the Forest Products Laboratory, where we can accurately control and measure saw size, number of teeth, type of teeth, saw speed, feed speed, and other factors that influence chip quality as well as the quality of the lumber produced. The results should be published in the near future and will serve as a guide to expanding the use of chip saws and maintaining chip quality.

The storage of round pulpwood has been under investigation for many years. During and before the war, much wood was peeled and penned in the woods. The Forest Service made studies of deterioration under these conditions. In subsequent years the practice was to pile unpeeled wood in huge piles as the pulp mills. Again, studies were made of deterioration of different species and under different storage conditions. In general, it was learned that underwater storage was best, piles sprayed with water next best, unpeeled wood stored dry next, and peeled wood stored dry the poorest.

More recently the interest has been in the storage of chips without cover. I have observed chips stored outside for periods of two or more years in dry areas of the West where no deterioration was evident. This certainly does not mean that we can expect the same thing in the South because the less decay resistant southern pine chips will be stored under conditions favorable to mold and decay. We are now cooperating with St. Regis Paper Co. in a study of the storage of pine chips at Fargo, Ga. Perhaps many of you have seen the working plan for this study that was distributed by APA.



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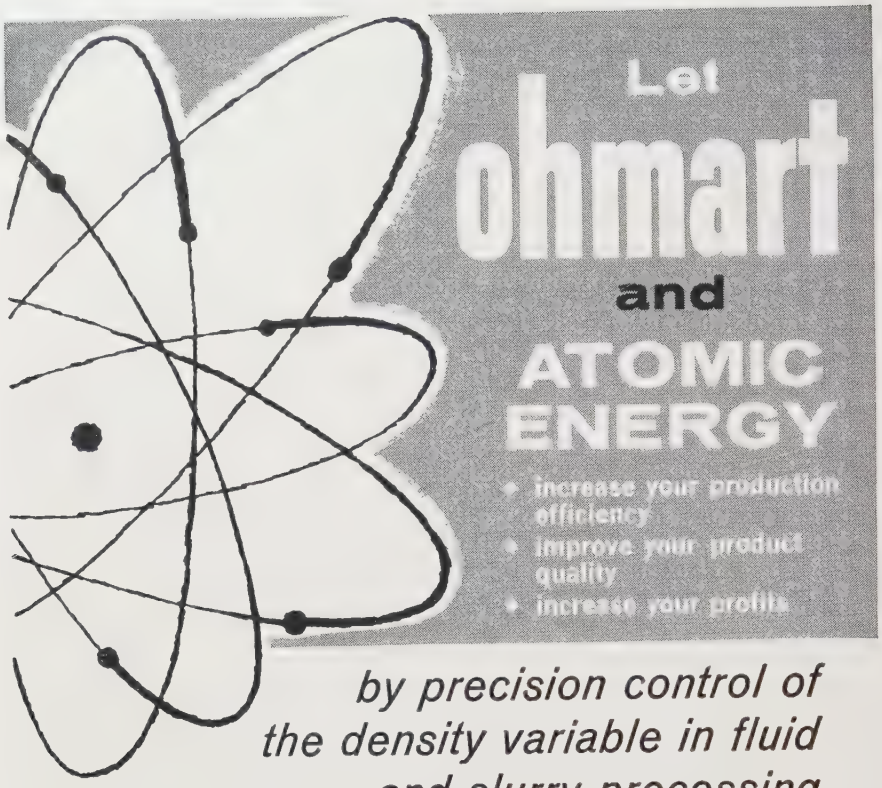

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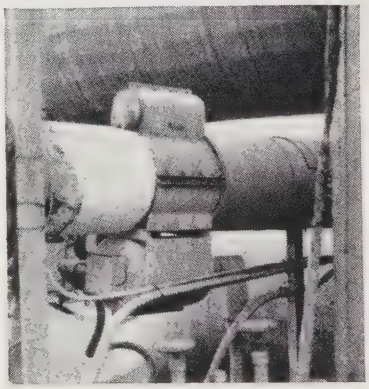

Caustic evaporator employing Ohmart Density System to maintain a constant percent of solids.

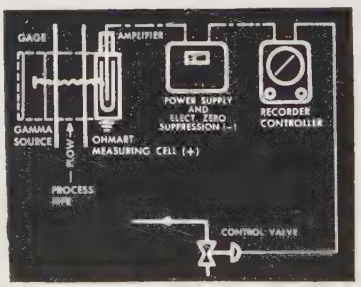

Diagram shows typical Ohmart Density Control System where control of liquid density is by actuation of a valve.

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We have completed a 5-month test under severe summer conditions and, although I cannot release full information on the results in advance of a complete analysis, I can say that after 90 days of summer storage there was no appreciable decrease in specific gravity, pulp yield, or pulp quality. We did find that the pile increased in moisture content and temperature and that several stains and molds became evident in portions of the pile. A full report will soon be published on this study.

Now we have established another chip pile and will study it under winter conditions and carry a portion of the pile on until we get serious losses in specific gravity, the best known measure of pulp yield and quality. Subsequent work might involve water sprays or even chemical treatments, if such is deemed advisable. We are enthusiastic about open chip storage because it offers attractive opportunities for mechanization in handling raw material. So far our research on chip storage has been confined to southern pine, but we hope to secure industry cooperation and conduct parallel studies on hardwood chips.

DIVERSIFICATION THROUGH GREATER USE OF HARDWOODS

The piney South contains a greater volume of hardwoods than pine. Most of the southern pulp industry, however, was built on the use of pine for kraft pulp. The pendulum is now swinging with a trend toward diversified products and a greater use of hardwoods percentagewise as well as volumewise. Part of this has been made possible by new pulping processes, new bleaching techniques, and the increasing pressure on the supply of pine. The semichemical method developed at the Forest Products Laboratory lay on the research shelves for some years but it is now being used widely to pulp hardwoods with increasing pulp yields. The cold soda process is a more recent development at Madison and is just beginning to get the attention it deserves. The pulp yields approach groundwood pulp yields and the process is quite susceptible to a continuous operation with a roller type press-digester, if it is proper to term it a digester. Adaptations and hybrids of these

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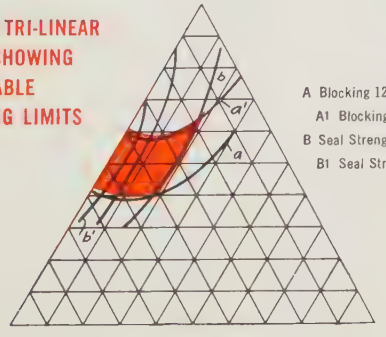
As an example, wax coated wrappings for frozen foods must furnish good blocking resistance for easy handling and stacking . . . strong heat seal to retain freshness and flavor . . . low moisture vapor permeability . . . and attractive high-gloss appearance. The characteristics of each component in such a coating would be plotted on the chart to form the envelope-shaped area indicated here in red. Any proportion of the waxes within this area may be satisfactory for frozen foods packaging.

TYPICAL TRI-LINEAR CHART SHOWING ACCEPTABLE BLENDING LIMITS



But that's only half the task. Converting equipment, methods and the packaging material used vary widely throughout the industry. It therefore requires the experience and technical knowledge of the Atlantic Sales Engineer . . . backed if necessary by Atlantic's extensive research facilities . . . to discover within the general area a composition best suited to each individual use. This basic method of exact blend determination can be applied to any field where wax blends are used.

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processes permit a pulp mill to design the process to the desired product. Unquestionably we are going to see more and more hardwood, roundwood and chips, coming to the mill for every type of product from newsprint to high quality food container stock.

The hardwoods with shorter fibers have bulking qualities and other characteristics that contribute to improved characteristics in most paper products when they are properly blended with the longer pine fibers. Research is continually pointing the way to new possibilities along these lines. Likewise, the forest management and wood procurement problems become simpler when the hardwood takes its proper place in the pulp industry.

SPECIAL UTILIZATION PROCESSES AFFECTING PULP INDUSTRIES

One of the biggest problems facing your industry, as well as the lumber industry, is the use of tremendous volumes of bark. At present, most bark is burned as fuel, but it is not ideal for this purpose and has other possibilities of far greater value.

Bark is an intriguing raw material for new chemicals. In the Forest Service, we have started research in this field, but I hasten to add that we have only taken one step when we have miles to go. We will continue to conduct basic research on bark at the Forest Products Laboratory but we need a lot of industry help, especially in the application field to determine useful products and to develop pilot plant studies. This applies to the whole field of wood chemistry and not just to bark chemistry.

Bark can be converted to charcoal in a continuous carbonizing process being perfected by the Charcoal Industries, Inc., at Conway, S. C. Bark makes a good charcoal that can be briquetted and marketed for outdoor cooking. The process in South Carolina, developed by a Canadian, employs a unit that will produce from 5 to 10 tons of charcoal each 24 hr., utilizing about 30 tons of the undried bark. The cost of the equipment for carbonizing is not much more than many firms spend for residue burners to get rid of bark.

Pine bark has been used for agricultural purposes, such as composting, animal bedding, and mulching. In the Forest Service we have not conducted research on this because the Department of Agriculture feels that this more properly lies in the province of the State Agricultural Experiment Stations. Some work has been conducted by industry and through contract research with Teco and the Herty Foundation. Unfortunately, our Agricultural Experiment Stations have shown little enthusiasm for research along this line.

I have previously mentioned the development of new chemicals from wood and bark. I firmly believe that in another 20 years, wood chemical industries in the South will be using almost as much wood raw material as the paper industry is using today. I have been debating in my own mind whether this new industry is going to spring up as a part of the pulp and paper industry or whether it will be separate and competitive to some degree. I am inclined to believe that some of you are going to be very influential in making that decision. With a broadened outlook and a vigorous research program, you are in a position to take the lead in a wood chemical industry. You have the timberland, the raw material, the transportation system, the sales organization, and the technical ability. You will start, as many of you already have, to develop chemicals from bark and from your plant effluent. You can expand this chemical industry by bringing more raw material in from the forest that is currently being left.

Such a chemical industry must be diversified; previous attempts at producing one chemical have proved uneconomic. At the Forest Products Laboratory we are looking for new ways to break down wood so that we do not degrade many components to obtain one. We hope that this may be the secret to a wood chemical industry and that before many years pass, the cellulose fiber may be a by-product rather than the only source of income. Then we will be approaching true and full utilization of our wood resource.

WHAT OF THE FUTURE

The chain saw has been a big help and I am sure it will continue in the picture for some time to come, but I do not believe that we will continue to cut up our trees into 5-ft. lengths. Already many of you have converted or are considering conversion to tree-length logging. Personally, I think that the pulpwood industry is almost certain to go to full tree chipping in the forest. There are only a few roadblocks to such an operation at the present time. The biggest one involves the separation of bark, needles, and unusable fines after the material is chipped. Although several investigators have tried air separation, flotation methods, etc., no one has been very successful in whipping this problem.

Most past efforts have been of the empirical type or trial and error method. We need to conduct more fundamental research to determine the differences in bark and wood, the chemical changes that make bark slip in the spring, and other factors that might give us a lead toward a better method of separating bark and wood.

Another big obstacle is transportation. Chips are bulky and costly to move by conventional trucking methods. We should take our cue from the petroleum industry and seriously consider blowing or pumping chips in water through pipes, probably all the way to the pulp mill, or at least to major arteries of traffic. This is not as ridiculous as it may first appear, if you will stop to figure the investment you now have in rolling stock and add to this your freight costs.

Airplanes or helicopters are going to be used for hauling wood, but I believe it will be a long time before they become economical for anything more than a short haul from very inaccessible locations.

It is inevitable that we must put every acre of land to work and get the maximum production from each acre. We can no longer depend on nature to plant the seed and prescribe the growing conditions. We must use certified seed and we must use cultural practices and improved equipment that will assure the maximum returns on our forest investment. This is going to require more research in the future than we have ever dreamed of in the past, and this research must be a combined cooperative effort of government, schools, and industry.

Presented at the meeting of the Southeastern Section of the Technical Association of the Pulp and Paper Industry, held in St. Simon's Island, Ga., Nov. 20, 1959.

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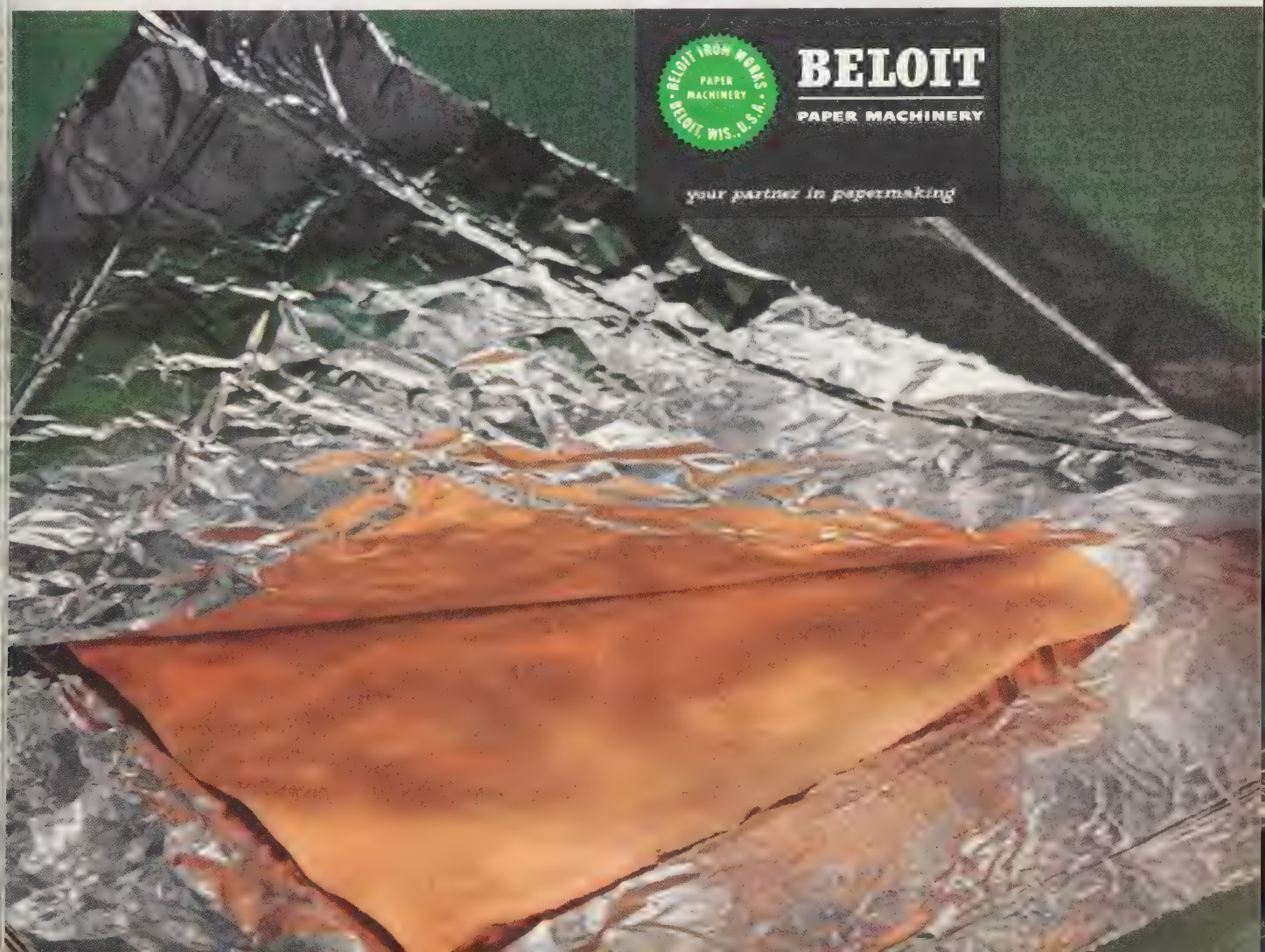
A PAPER "SANDWICH" YIELDS NIP BEHAVIOR DATA. PHOTOS BY S. R. CHRISTENSEN



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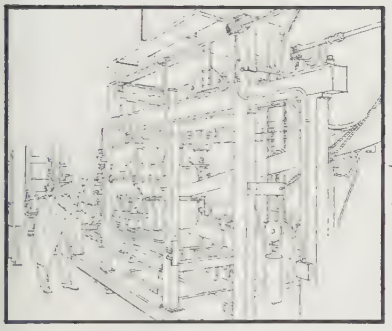

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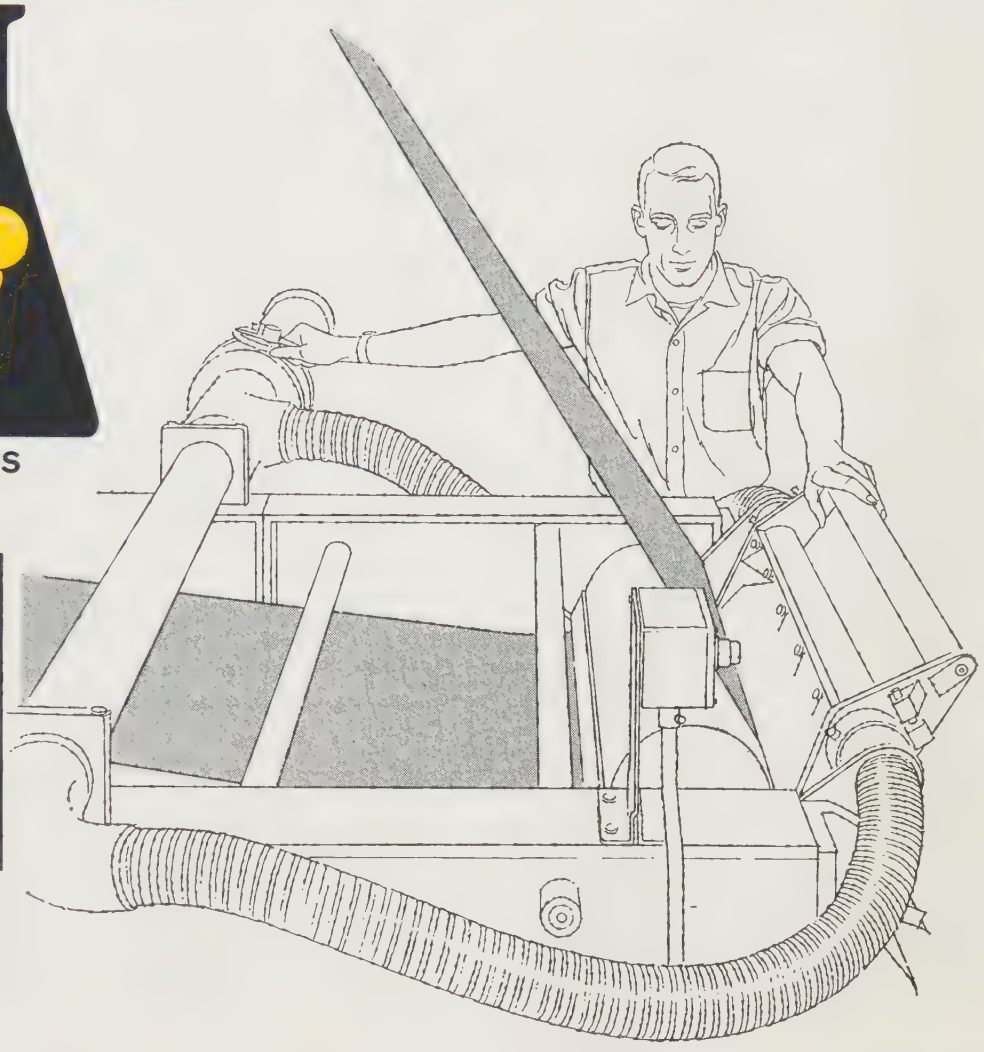

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Calculation of the Rate of Return on Investments

RAY I. REUL

THE capitalistic system, our way of life, is based upon the principle of private ownership of property and the right of the possessor of such assets to employ them to produce an income or profit. All sorts of laws and taxes have been devised to restrict and limit the opportunity to exercise this privilege, but this basic philosophy continues to be the guiding principle behind our economic actions.

The use of assets to produce a profit may be described as the deliberate act of placing these assets "in jeopardy" or "risking them" in anticipation of future reward or gain. Assets thus employed are commonly labeled investments. The income generated by these investments is called the return or yield.

As participants in this economic system, we and the enterprises with which we are associated, often find it necessary or desirable to invest available assets. In order to avoid making investments which will not be profitable and to locate and select from those available to us, those with the greatest possible yield, we should endeavor to use the best possible techniques for predicting performances.

The derivation of a reasonably simple, universally applicable method of evaluating the yield obtained, and relating same to the amount and length of investment commitment, requires little more than simple arithmetic.

The computations involved do not represent a particularly difficult mathematical problem, but a thorough understanding of the basic principles and concepts required to apply these mathematical techniques correctly, and to interpret the results obtained properly, is not quite so easy to acquire.

The selection of the best method of evaluation poses some problems. But these are minor when compared with the difficulties of gaining and maintaining acceptance of the validity and reliability of an objective method. One reason for this situation is the ritualistic fog and professional mystery which are still associated with this subject and which often result in stubborn adherence to concepts long proved fallacious. Another is the seemingly endless variety of so-called "new" evaluation techniques which have and continue to be proposed by an army of self appointed experts. These vary from simple rules of thumb to elaborate methods of great complexity. Some of these are completely spurious. Many can be demonstrated to have only limited validity. The remainder are merely variations of the basic rate of return approach.

It is heartening, however, to observe how a better understanding of the factors and techniques concerned with investment evaluation are arising out of the present welter of bickering and confusion and how the need for greater management effort and efficiency in this area is receiving increased recognition.

R. I. REUL, Food Machinery & Chemical Corp., New York, N. Y.

It is the intent of this paper to present a logical derivation of the rate of return method, demonstrate its validity and value, point out refinements which can be included, illustrate practical applications, and warn against its use without a thorough understanding of the principles involved.

DERIVATION OF THE YARDSTICK

Economically justified investments are made for a wide variety of purposes. Some are designed to produce a stream of future incomes, others a more valuable asset at a future date. Many are predicted to produce a combination of the two. There is, however, one aspect common to every investment proposal. This is that each represents a plan for the risking of currently available assets in exchange for anticipated future gain.

This description highlights the three basic factors which must be considered in all investment proposal evaluations:

1. The size of investment—or the value of the assets risked.
2. The amount of income—or the reward to be gained.
3. The timing—or the time relationship between (1) and (2).

It is common practice to express the relationship of these three variables as a ratio and to use this figure as a measure of proposal performance.

$$\text{Performance ratio} = \frac{\text{Units of income}}{(\text{Units of investment}) \times (\text{Units of time})}$$

Using the conventional units: dollars for units of income and units of investment, years for the units of time, and expressing the ratio as a per cent, this formula is often written.

$$\text{Per cent annual return on original investment} = \frac{(\$\text{ income})/(\text{years})}{(\$\text{ investment})} \times 100$$

Sometimes this ratio is inverted and given a different name:

$$\text{payout} = \frac{(\$\text{ investment})}{(\$\text{ income})/(\text{years})}$$

Essentially the same, and quite simple to calculate, they are considered "practical" yardsticks and are quite widely accepted as a means of measuring investment performance. Actually, they are "practically useless." These yardsticks are inconclusive and frequently misleading. This is because they do not take into consideration the length of time over which the ratio applies. To illustrate, let us explore how they would evaluate the three investment proposals shown in Table I. You will note that all three are evaluated exactly alike despite the fact that the earnings of proposal B are only half of those in proposal A, and proposal C doesn't even pay back the original investment.

The simplest way to build recognition of the duration of income into this ratio is to include an item called

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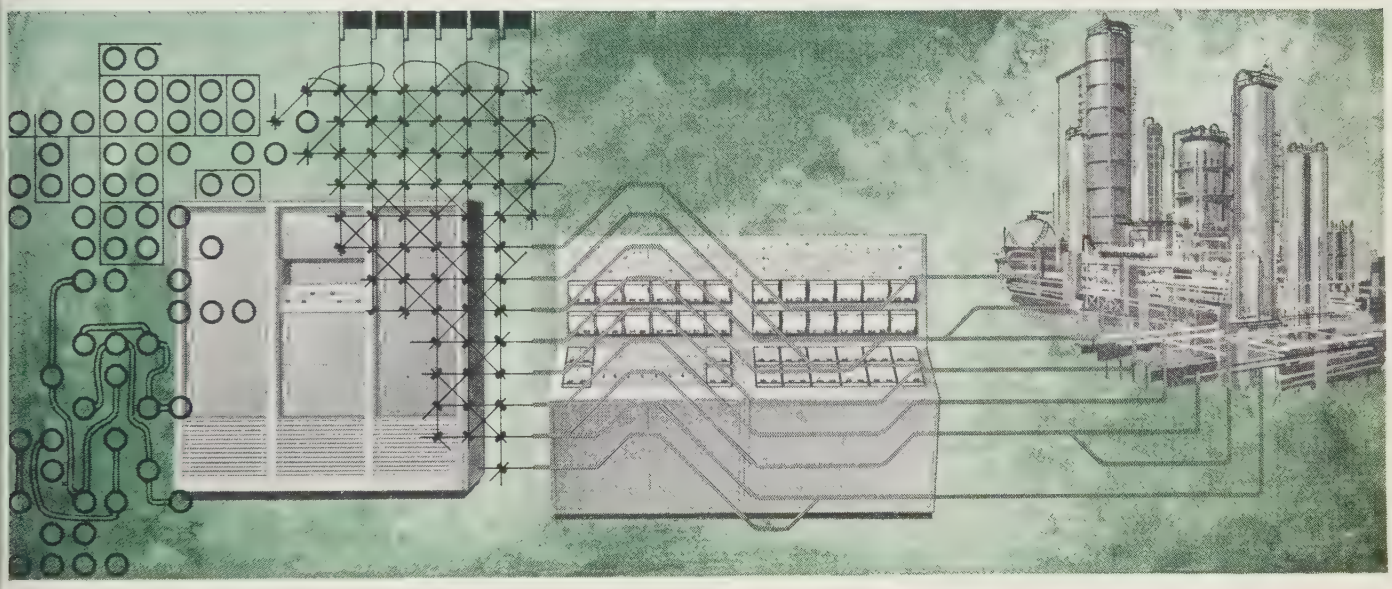

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Table I

	Proposal A	Proposal B	Proposal C
Investment	$1000	$1000	$1000
Income year			
1	300	300	300
2	300	300	300
3	300	300	300
4	300	300	...
5	300	300	...
6	300	...	...
7	300	...	...
8	300	...	...
9	300	...	...
10	300	...	...
	$3000	$1500	$900
Annual return on original investment	30%[a]	30%	30%
Payout	3 1/3 yr.[b]	3 1/3 yr.	3 1/3 yr.

[a] Sample calculation $\frac{3000}{1000 \times 10} \times 100 = 30\%$.

[b] Sample calculation $\frac{1000}{3000/10} = 3\frac{1}{2}$ years.

amortization or recovery of the investment. Applying the commonly used convention of uniform or straight line "end of the year" amortization, this yardstick may be written:

$$\left(\begin{matrix}\% \text{ Average Annual Return} \\ \text{on Weighted Average Investment}\end{matrix}\right) = \frac{(\$ \text{ Total Receipts}) - (\$ \text{ Investment})}{(\text{Weighted Average Investment}) \times (\text{Years})} \times 100$$

Table II shows this new yardstick applied to the same three investment proposals shown in Table I. These data immediately show that proposal C has no return and that the return on proposal B is as it should be, much less than the return on proposal A.

Now let us consider another problem. Table III, showing proposals, J, K, and L, demonstrates its nature. It shows three investment proposals, each yielding a quite different "pattern" of receipts, yet the total of receipts is the same in all cases. The yardstick which we have just demonstrated, the average annual return on the weighted average investment, rates all three proposals the same. Yet it is obvious that proposal K is the most desirable. Thus we find that the different patterns of receipts do not affect our yardstick. This is because we are using average receipts in our calculations. This is somewhat reminiscent of the statistician who couldn't swim and drowned while crossing a stream which he had proved to have an average depth of only 6 in.

Your will recall that we are expressing our ratios as a per cent. Actually, we are measuring the average earnings per year as a per cent of the weighted average unamortized investment. In a situation where we have uniform annual receipts and amortization, it can be demonstrated mathematically that this per cent is roughly equivalent to the annual interest rate which states earnings as a per cent of unamortized investment. Therefore, it would seem reasonable that we could apply

Table II

	Proposal A	Proposal B	Proposal C
Average annual return on weighted average investment	36%[a]	16 2/3%	No return

Sample calculation

$$\frac{(\$3000 - \$1000)/10}{1000 + 900 + 800 + 700 + 600 + 500 + 400 + 300 + 200 + 100} \times 100 = 36\%.$$

Table III

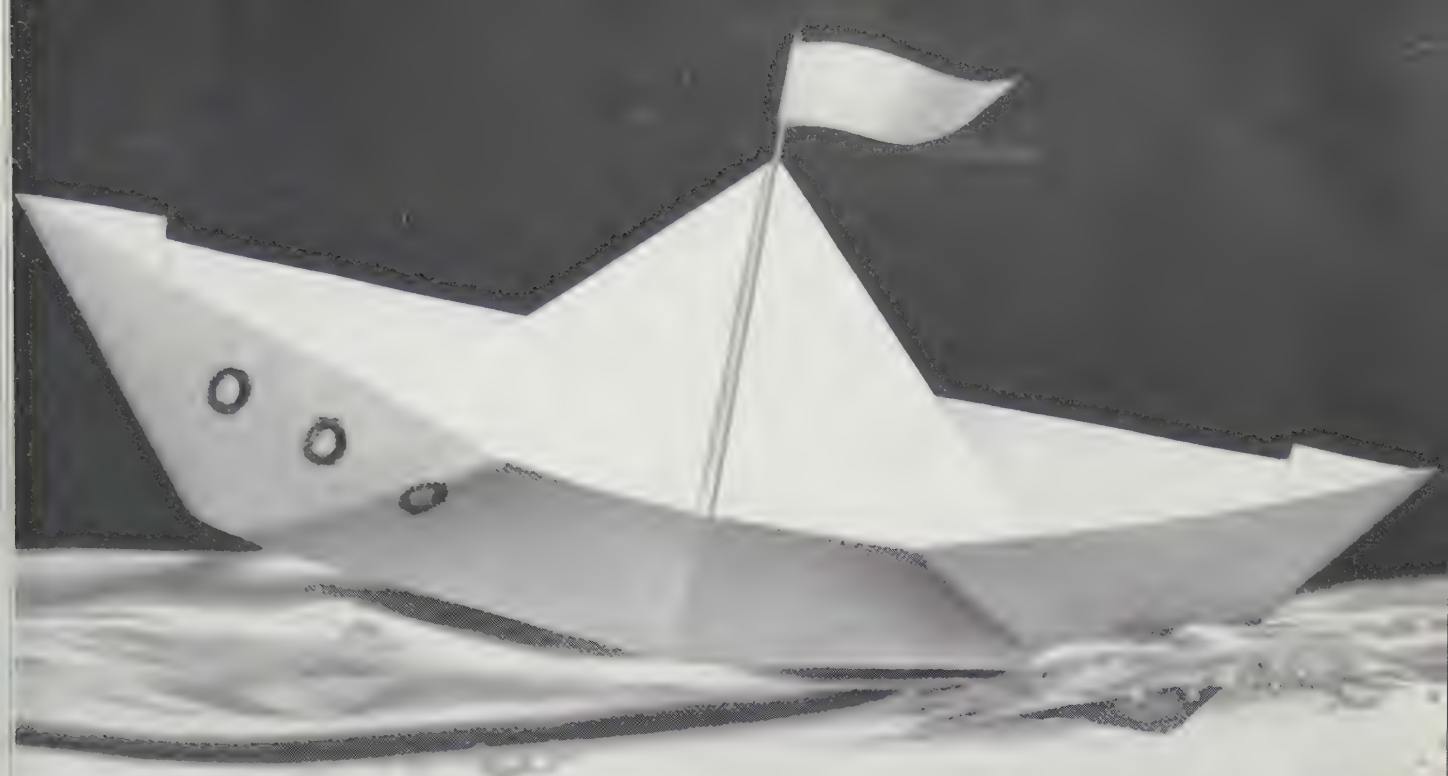
	Proposal J	Proposal K	Proposal L
Investment	$1000	$1000	$1000
Income year			
1	300	1100	100
2	300	100	100
3	300	100	100
4	300	100	100
5	300	100	1000
Total	$1500	$1500	$1500
Average annual return on weighted average investment	16 2/3%	16 2/3%	16 2/3%
Profitability index	17 1/2%	40%	11%

interest methods to the measure of investment proposal profitability, call the figure thus obtained the *rate* of return and define it as the *interest rate* on the unamortized investment. This is of great importance because interest methods have the distinct advantage of permitting the development of individual factors for separately relating each year's receipts to the investment and thus make it possible to take varying income and expenditure patterns into consideration in evaluating the project earning rate.

This approach, however, creates another problem. What plan should be used for amortization or repayment of the original investment? The nature of this problem is demonstrated by the tables shown in Table IV which shows five different plans for repayment of an investment. In all cases, the investment is $5000 and

Table IV. Five Plans for Repayment of $5000 in 5 Years at 8% Interest

Plan	End of year	Interest due at year end	Owed before year end payment	Year end payment: Interest	Year end payment: Principal	Year end payment: Total	Owed after year end payment
I	1	$400	$5400	$400		$400	$5000
	2	400	5400	400		400	5000
	3	400	5400	400		400	5000
	4	400	5400	400		400	5000
	5	400	5400	400	$5000	5400	0
	Total			$2000	$5000	$7000	
II	1	400	5400	400	1000	1400	4000
	2	320	4320	320	1000	1320	3000
	3	240	3240	240	1000	1240	2000
	4	160	2160	160	1000	1160	1000
	5	80	1080	80	1000	1080	0
	Total			$1200	$5000	$6200	
III	1	400	5400	400	853	1253	4147
	2	332	4479	332	921	1253	3226
	3	259	3485	259	994	1253	2232
	4	179	2411	179	1074	1253	1158
	5	94	1252	94	1158	1252	0
	Total			$1264	$5000	$6264	
IV	1	400	5400				5400
	2	432	5832				5832
	3	459	6291				6291
	4	495	6786				6786
	5	535	7321	$2321	$5000	$7321	0
	Total			$2321	$5000	$7321	
V	1	400	5400	200		200	5200
	2	416	5616	616	1384	2000	3616
	3	289	3905	289	711	1000	2905
	4	232	3137	232	1768	2000	1137
	5	91	1228	91	1137	1228	0
	Total			$1428	$5000	$6428	
V(a)	1	400	$5400		200	200	5200
	2	416	5616		2000	2000	3616
	3	289	3905		1000	1000	2905
	4	232	3137	200	1800	2000	1137
	5	91	1228	1228	0	1228	0
	Total			$1428	$5000	$6428	



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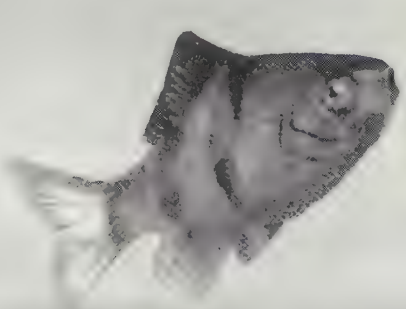

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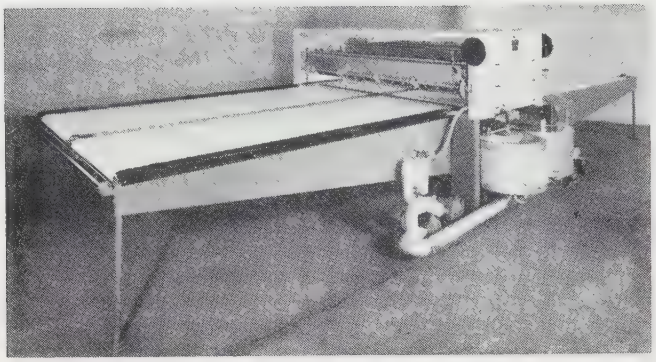

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the interest rate applicable to the unamortized investment is 8%.

The first thing which is strikingly apparent is that while in every case the investment and interest rate are identical, the total amount of payments varies widely. The sole cause of this variation is the use of a different investment amortization pattern in each plan. In our rate of return calculations we are solving for a different variable, interest rate, but the same three factors, investment, income, and time are involved, so the problem remains.

The earning rate calculated for a proposal will vary with the amortization plan assumed. Amortization equivalent to straight line depreciation will result in the calculation of one interest rate. A quite different interest rate will result from assumption of an amortization plan equivalent to sum-of-the year's digits depreciation.

Now may I call your attention to plans V and V(a). You will note that if the specified payment (receipts) schedule is held unchanged, the answer is unchanged over a wide range of amortization plans. This is called the annuity approach. When this method is used, no specific amortization plan is assumed. The interest factors used, which are usually called "present worth factors" include provision for amortization of the investment.

The rate of return methods known by the names "Investor's Method," "Interest Rate of Return," and "Profitability Index" are essentially the same, and are all based upon this approach. The answer they calculate is the interest rate that an annuity fund, equivalent to the amount invested in the project, would have to earn in order to make payments equivalent (same amount at same time) to the earnings of the project. It is the average earning rate of the project over its entire life.

There are two minor revisions in conventional interest computation methods which are recommended when they are applied to investment proposal evaluations:

(a) *Continuous Receipt of Income:* The usual convention is to assume end of the year receipt of income. In most investment projects, however, income is received during the year. When this is so, the assumption of continuous receipt is a much more accurate approximation of actual experience. Interest factors, adjusted for the assumption of continuous receipts are readily available and just as easy to use.

(b) *Continuous Compounding:* Many different compounding periods are used by business and financial institutions. Annual, semiannual, quarterly, and monthly periods are the ones most frequently encountered. The selection of a method different from all of these is recommended for three reasons:

(1) By selecting a method different from all those currently in use, there is no implication of partiality toward any specific practice.

(2) In most cases, the answers obtained through the use of continuous compounding will be only slightly different from those obtained via use of one of the conventional approaches.

(3) In all cases the answers obtained will be more conservative than those obtained via the use of conventional periods. And the higher the yield, the more conservative the measurement.

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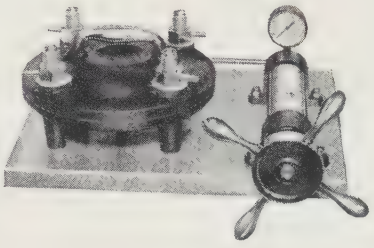
Pulp Testing and Sheet Making Apparatus

TAPPI SHEET MAKING MACHINE

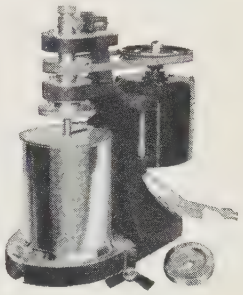
Bronze, brass and stainless construction throughout except couch roll which is heavily chrome plated. Drying Rings with gaskets and Drying Discs available but not illustrated. (T-205 m)

TAPPI PUMP & PRESS



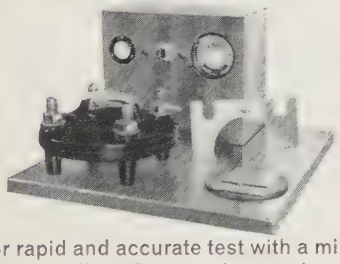
Mounted on 18-8 Stainless steel base. Press on base, or pump only may be purchased separately. (T-205 m)

TAPPI DISINTEGRATOR



Standard equipped with bronze chromium plated container bowl and stainless steel chuck, collet and shaft assembly. (T-205 m)

TAPPI PRESS WITH AUTOMATIC CONTROL



For rapid and accurate test with a minimum of effort. Base and control cabinet 18-8 stainless steel.

AUTOMATIC COUCHING DEVICE FOR SHEET MACHINE and FIBER LENGTH CLASSIFICATION GRID PLATE

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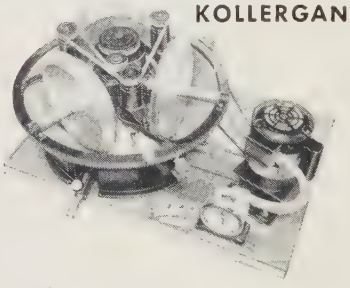
IMPROVED PRECISION KOLLERGANG



The only instrument that will give truly reproducible beating results. (T-225 sm)

This line of equipment features the ultimate in pulp testing and sheet making apparatus. Latest improved corrosion resistant material is used on all parts coming into contact with pulp solutions used in testing. The operational precision, durability and beautiful finish will command greater laboratory efficiency and cleanliness. All the Tappi Standard approved apparatus also bears the official seal and registered serial number of the Papermakers Association of Great Britain and Ireland.

HERMANN MANUFACTURING CO.

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Table V.

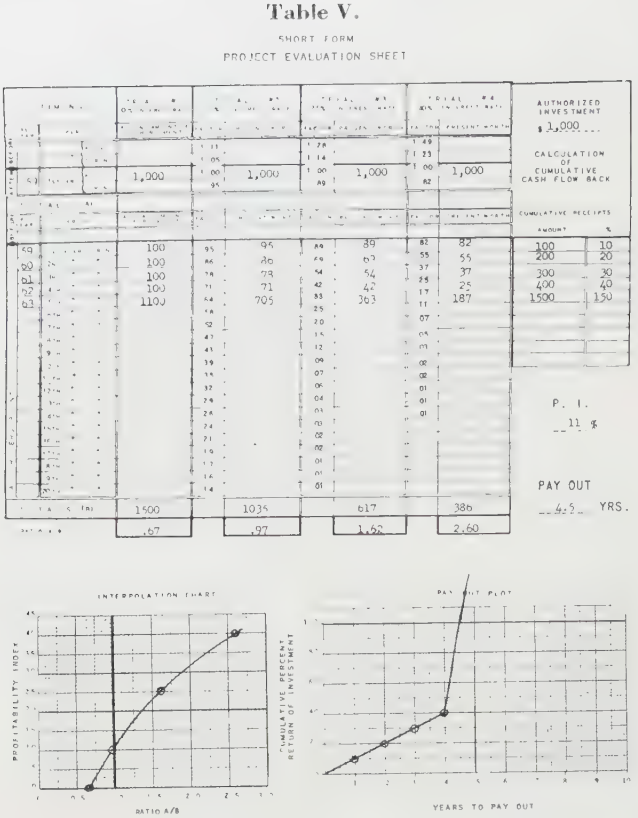


Fig. 1. Short form project evaluation sheet

The Profitability Index, which was introduced in my company some years ago, together with several other rate of return methods, use the continuous receipt, continuous compounding convention.

HOW TO CALCULATE RATE OF RETURN

The calculation of an equivalent average interest rate from investment and receipts data requires the use of the principle of equivalence plus trial and error techniques. The principle of equivalence is quite simple. We use it to express the time value of money. For instance, \$97.17 invested today, at 3% interest rate will be worth \$100 one year from now. Thus we can say that at an interest rate of 3%, \$100 to be received 1 year in the future is equivalent to \$97.17 today. It is conventional practice to call this current equivalent value, the *present worth* at that interest rate.

The traditional way of determining the *solution interest rate* from data stating original investment and receipts is to select a convenient arbitrary *zero time*, convert all investment and receipt amounts to their present worth at that *zero time* at various trial interest rates until an interest rate is found at which the algebraic sum of all the present worths is zero. This is the interest rate equivalent to the average earning rate of the project.

EXAMPLE OF CALCULATION USING PROFITABILITY INDEX CALCULATION SHEET

The Profitability Index is unique only in that standardized data check lists, pretabulated work sheets and graphical interpolation methods are used. These help insure completeness of data, increase speed and accuracy of data compilation, and simplify the calculation procedure.

Table V Figure 1 shows the complete calculation of the Profitability Index for the following sample problem:

Investment at start of year 1959	\$1000
Receipts during 1959	100
Receipts during 1960	100
Receipts during 1961	100
Receipts during 1962	100
Receipts during 1963	1100
Total	\$1500

The detailed procedure is as follows:

1. The zero time is selected as the beginning of the first year in which an income is received.(From a mathematical point of view, any zero time can be used. The above choice is dictated only the design of the forms.)

2. Each cash flow: investment (disbursement) and income (receipts) is entered in the column headed "Actual Amounts-0% Interest Rate" on the lines which best describe the time at which each increment of cash flow is predicted to take place.

3. The third step is to calculate the "Present Worth" of each increment of cash flow at the three trial interest rates 10, 25, and 40%, using the present worth factors shown for each trial interest rate. The first column is the present worth at 0% interest.

4. Next we add each column as shown to obtain the total present worth of each set of cash flows at these interest rates.

5. We know, that at the *solution interest rate* we are seeking to calculate, the total present worth of the cash outflows and flowbacks will be identical. While it is quite likely that the trial interest rates we have used will bracket the answer we seek, we can scarcely hope that any one will be the exact answer. Therefore, to find the exact answer, we interpolate graphically as follows: First, we divide the total present worth of cash outflows by the total present worth of the cash flowbacks at each trial interest rate, including those at 0%

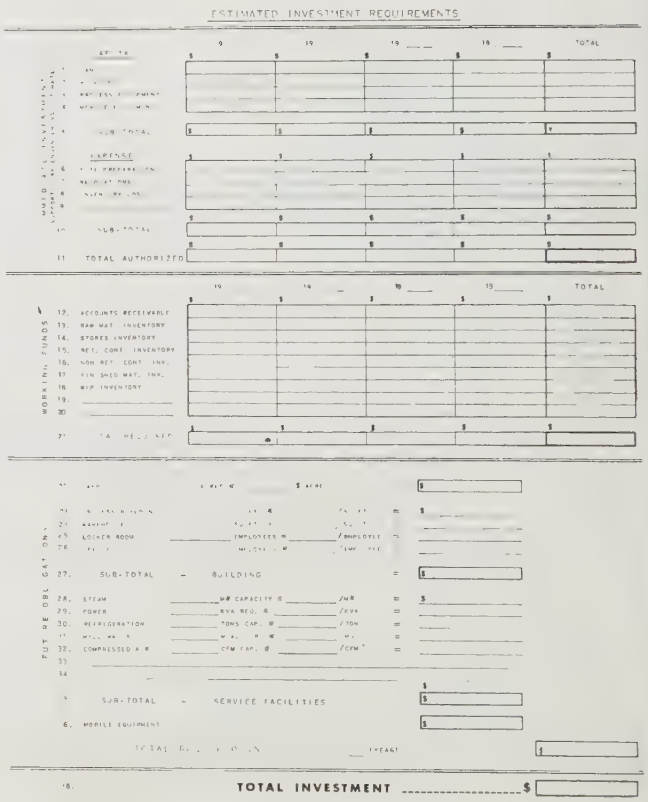
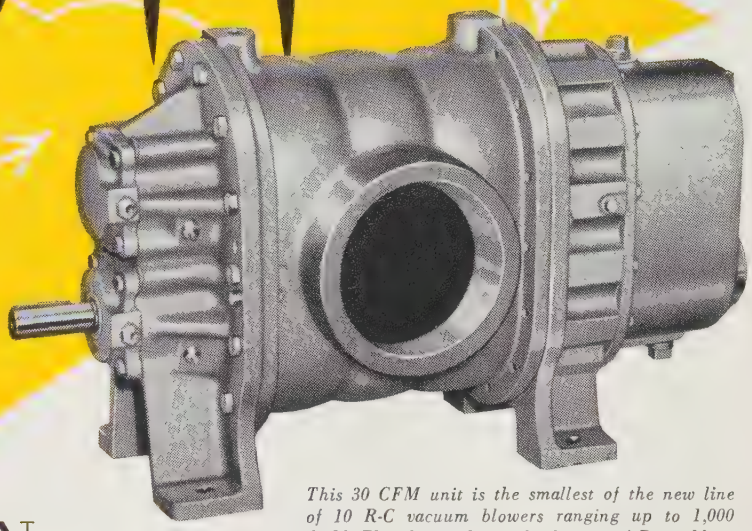


Fig. 2. Estimated investment requirements

NOW

for efficient vacuum service as low as 30 CFM...



This 30 CFM unit is the smallest of the new line of 10 R-C vacuum blowers ranging up to 1,000 CFM. They bring the total selection of Roots blowers to 46 sizes...with savings for you in every size.

A BIG SELECTION OF SMALL ROOTS VACUUM BLOWERS

Roots-Connersville adds 10 small-volume vacuum pumps to its already extensive line to give you better selection, better performance in limited-volume applications. This new line is designed to handle capacities ranging from 30 CFM to 1,000 CFM, for operation at up to 20 inches mercury vacuum in single stage construction. These units are designed for compounding for higher vacuum service.

Major features of the larger Roots water-sealed units are retained: simple, efficient design without internal valves, no internal contact between moving parts, normal maintenance limited to oil changes, efficient operating speeds and minimum sealing water requirements. The result is more CFM per dollar.

Only Roots-Connersville offers exclusive rotary positive design and such ease of installation in vacuum blowers of this size. They are now available for a wide variety of application in the food, chemical, petroleum, paper, sewage and industrial waste treatment, mining and other industries.

Your nearest Roots-Connersville sales engineer has full details on this new series of vacuum blowers. Or write for a specification sheet and for Bulletin VP-158 covering the larger units.

ROOTS-CONNERSVILLE BLOWER
DIVISION OF DRESSER INDUSTRIES, INC.
560 Maple Ave., Connersville, Indiana. In Canada—629 Adelaide St., W., Toronto

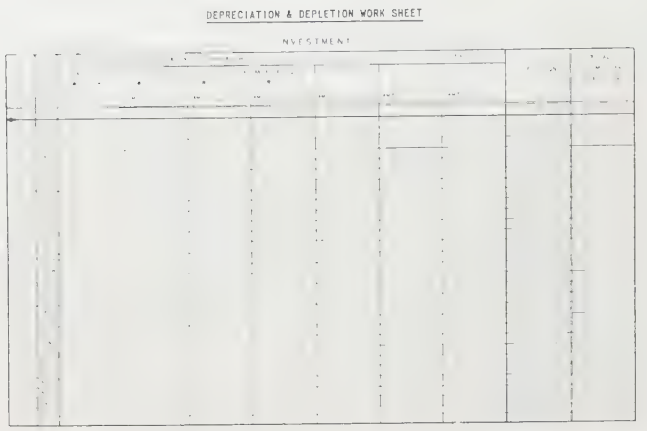


Fig. 3. Depreciation and depletion work sheet

interest rate. The ratios thus obtained are plotted against the trial interest rate at which they were calculated, on the chart shown at the bottom of the exhibit. The height at which this curve intersects the "unity ratio" line may be read off on the ordinate to find the interest rate applicable. This is the Profitability Index. It is the interest rate at which a sum, equivalent to the investment, would have to be invested in order for the sum of the principle, plus the interest earned, to be just sufficient to make payments equal to the earnings of the proposed project.

Figure 1 has been presented on what we call in our company the "short form." This form is used for informal evaluations. There is also a set of five forms (Figs. 2–6) which are used when making an evaluation to be included as part of a formal request for funds for a large investment. The principles involved are the same. However, the five-part set encourages a more

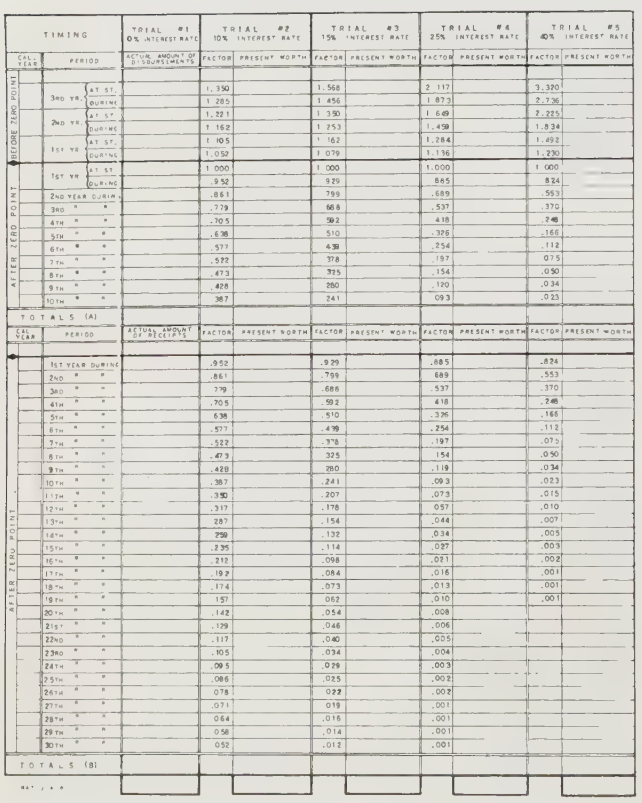


Fig. 4. Calculation of profitability index

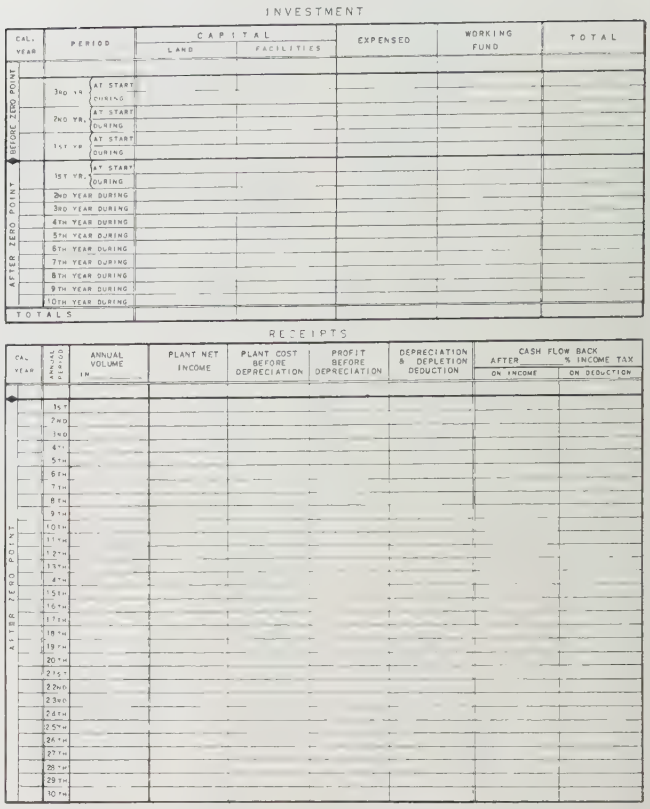


Fig. 5. Time schedule of expenditures and recipts

complete job by providing: (a) check sheets to promote collection of more complete data, (b) calculation sheets to standardize calculation methods, and (c) more accurate computation tables and chart.

Table V also shows a calculation of *payout* years. This has been included as a crude measurement of one kind of risk. It calculates the minimum number of years the project must continue as predicted in order to return the original investment but no profit. *It does not measure all* risk nor is it a measurement of earning rate.

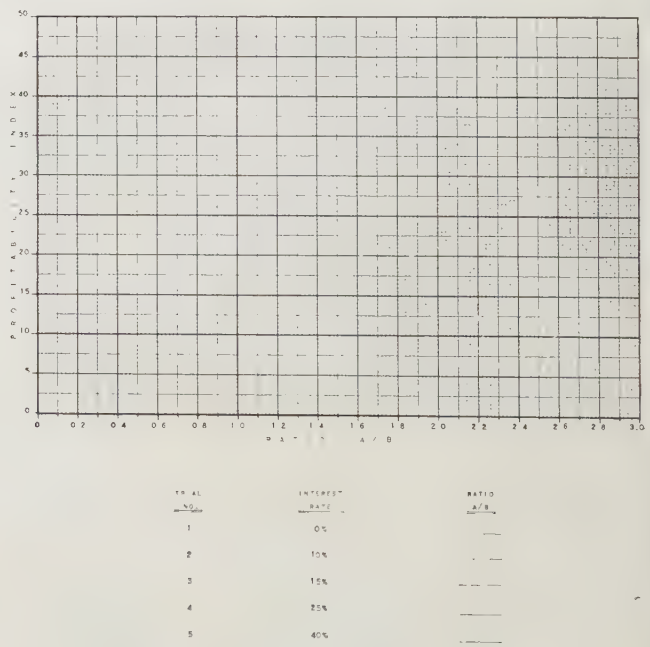


Fig. 6. Profitability index interpolation chart

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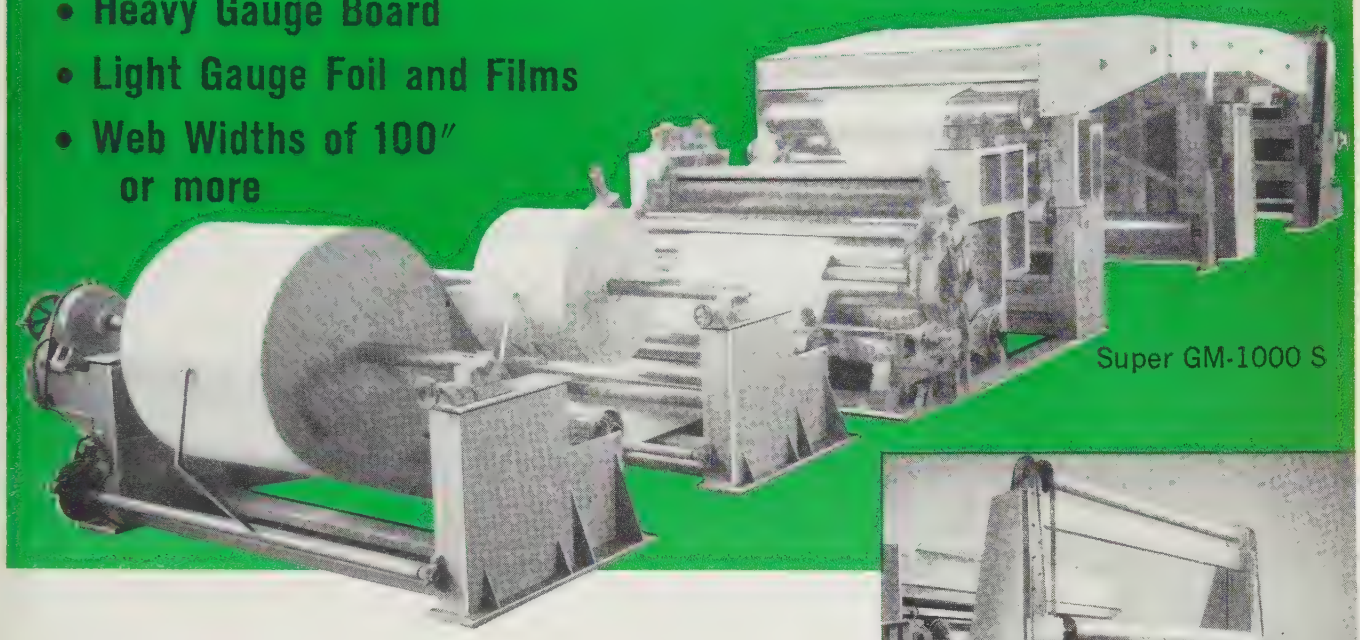
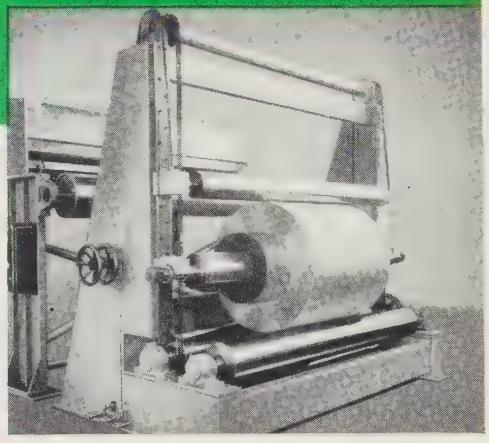
- **Heavy Gauge Board**
- **Light Gauge Foil and Films**
- **Web Widths of 100″ or more**



Super GM-1000 S

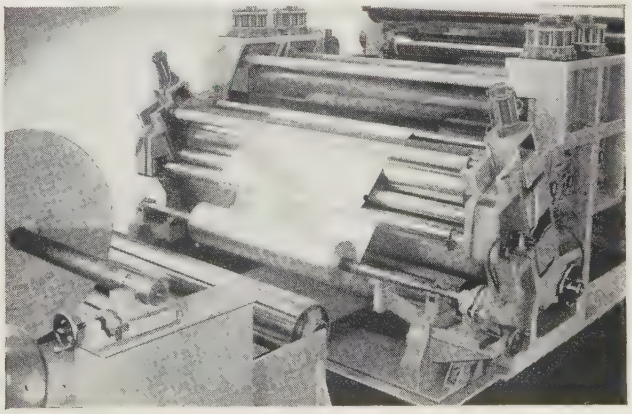


● Water cooling rolls at exit of the Super GM-1000 S drying tunnel, and surface type rewind which handles rolls up to 72″ in diameter.

More and more paper mills are extending their operations to include laminating and/or coating of the basic materials they produce.

The Inta-Roto laminator pictured above has been installed at the St. Joe Paper Company, Port St. Joe, Florida. This machine will enable St. Joe to produce high quality laminated and coated stock. The upgrading of their basic paper will mean new sales opportunities.

Inta-Roto laminators incorporate precision devices for tensioning, metering, and nip pressures to assure all-important quality control. These high speed precision machines are built on a unit basis so that you may add units to meet production changes or expansions.



● The Super GM-1000 S compact, precision station for application of adhesive and hot melts with two combining roll units.

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CAUTIONS TO BE OBSERVED IN MAKING RATE OF RETURN EVALUATIONS

Do Not Apply It to Noninvestment Proposals

The profitability index method, like other rate of return methods, has been designed to evaluate investments. If no investment is involved, the method cannot be used. Sometimes, because this mathematical limitation of the method is not realized, errors are made in its application. Since we are using years as our unit of time, expenditures and receipts occurring within the same year are mathematically concurrent as far as our calculations are concerned and cancel each other.

The following is a typical example of such a situation:

Year	*Contract time or lease payments*	*Receipts*
1	$500	$600
2	500	600
3	500	600
4	500	600
5	500	600

As you can see, there never is any money invested. Receipts each year are in excess of expenditures.

Here is an example of another type:

Plans are made to set up a "hot dog stand" which will require an investment of $1000 and yield an annual income of $300 for 5 years. The P.I. (rate of return) on this proposal is calculated to be 17½%. Now suppose a competitor comes along and offers $200 as an inducement to "not start up" this project. The normal inclination is to set up a rate of return calculation with $200 as the income, and zero as the investment. This leads to the conclusion that the return on this proposal is "infinity" and far better than building the stand which will yield only 17½%. Again, this conclusion is incorrect because no P.I. can be calculated if there is no investment.

Explore the Possibility of Restatement as True Investment Problem

The time or lease payment problem can be restated as a two-step problem and solved using rate of return methods. The first step is to set up an alternative purchase price. (A quotation for outright purchase can usually be obtained.) Then the projects earning rate is calculated on the basis of this investment. The cash flows being set up for calculation as follows:

Investment at start of year 1 (purchase price)	$1600
Receipts (cash flow from project)—year 1	600
year 2	600
year 3	600
year 4	600
year 5	600

The profitability index which is calculated to be 27%, is the true *earning rate of the project.*

Next we set up the cash flows as follows:

Investment at start of year 1 (purchase price)	$1600
Receipts (cash flow by avoiding lease or time payments)	
year 1	500
year 2	500
year 3	500
year 4	500
year 5	500

The profitability index of 20%, calculated from the foregoing data, is the *cost of borrowing money* via a leasing or time puchase agreement.

The earning rate of the project should be compared with the earning rate of other projects. The cost of leasing or time purchase should be compared with the cost of obtaining funds from other sources.

The "hot dog stand" problem is a simple illustration of the need for a little ingeniousness in setting up projects for evaluation.

Consider this approach: When the competitor offers $200 as an inducement to stay out of the business, a decision to go ahead and build the stand automatically calls for forfeiture of the $200. This means that the total cost of going into business becomes $1000 plus $200 or $1200. The P.I. calculated with the same income but with the larger investment becomes 10%. The obvious approach is to select the minimum P.I. you are willing to accept and calculate how much the competitor will have to pay to reduce your P.I. to this figure.

Never Include Book Value or Book Losses as Part of an Investment

The salvage value of existing facilities, plus any income tax advantages that can be obtained by their disposal are the only two items connnected with existing facilities which have any bearing on the evaluation of new investments. That portion of the original purchase price of existing equipment which has not been "recovered" by "depreciation" is called "book value." Neither this book value nor depreciation on same should be included in any new investment evaluation. Previously invested funds are "sunk" or gone and should not enter evaluation of future actions.

Depreciation is not a cost. It is an arbitrary method used by accountants to "charge off" prepaid expenses. Depreciation is not used in the calculation of rate of return. Interest factors used in rate of return calculations include provision for recovery of original investment.

Include Income Tax Impacts Where Pertinent

Income taxes should be included as a cost, just like any other costs. The only difference between income tax costs and other costs is that pretax profit must be calculated first because it is one of the variables used in calculating the amount of taxes which must be paid. Depreciation, depletion, and/or amortization enter into calculations at this point merely as deductions permitted by law in calculating income tax payments to be made.

Never Use Two Interest Rates in the Calculation of a Rate of Return

Many publications recommend using: the cost of capital, the average earning rate of capital, a sinking fund rate or some other interest rate as a supplementary "stipulated" rate in making rate of return calculations. Calculations made using this second rate will not yield correct project earning rates and may lead to erroneous conclusions. For instance: Baldwin, in a recent article in the *Harvard Business Review*, (May-June, 1959), recommends assuming the project's earnings to be reinvested at the enterprise's average earning rate. Mathematically this means compounding earnings forward to the last year of the project at the enterprise's

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After 170,000,000 gallons paper-plant bleach . . .

no corrosion in Saran Lined Pipe

This is the delivery end of a saran lined pipeline which carries a corrosive solution of chlorine dioxide bleach, 24 hours a day, seven days a week. The line transports the bleach liquor from storage tanks to a large pine pulp bleaching tower at the International Paper Company's Mobile, Alabama, plant. In the eight years this line has been in service, *there's not been a single failure in the Saran Lined Pipe.*

The plant also relies on Saran Lined Pipe to carry alum to a groundwood mill for pH control, and to carry waste acid salts to spray towers for soda and sulphur recovery. Because of the pipe's extreme resistance to corrosion and chemical activity; and because of its rigidity, which eliminates the need for continuous external support, International's engineers report they are ". . . enthusiastic . . ." about the use of Saran Lined Pipe.

For paper plants and for other chemical processing operations which require piping systems with extreme resistance to corrosion and chemical activity, Saran Lined Pipe is an ideal choice. Saran Lined Pipe, fittings, valves and pumps are available for systems operating from vacuum to 300 psi, from below zero to 200° F. They can easily be cut, fitted and modified without special equipment. For more information, write Saran Lined Pipe Company, 2415 Burdette Avenue, Ferndale, Michigan, Dept. 2286FC5.

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average earning rate and then finding the solution rate which will discount this total future value back to the original investment. The result is a weighted average return on the project and the other uses to which its earnings are put. The true earning rate of the project itself is obscured and projects which actually lose money will sometimes show a return when this method is used. Beware of using two interest rates in the same calculation.

VALID VARIATIONS OF THE RATE OF RETURN METHOD WHICH CAN BE USEFUL

Capitalized Cost Method

The usual approach in this method is to select a specific "stipulated" interest rate and compare the proposed investment with the present worth of its projected receipts at this interest rate, at a zero time selected as the year when the investment is made. It is also common practice to build into this analysis the assumption of an infinite series of replacements continuing *ad infinitum*.

To illustrate, the proposal evaluated by the P.I. in Fig. 1 would be evaluated by the capitalized cost method as follows: (using exactly the same continuous receipt—continuous compounding interest factors).

1. Set stipulated interest rate at say 10%. Calculate present worth of infinite series of investments and incomes as shown below:

Year	Investment	Income	10% Present worth factor—At an instant	10% Present worth factor—Received during year	Investment	Receipts
1	$1000	$100	1.00	0.95	$1000	$95
2		100		0.86		86
3		100		0.78		78
4		100		0.71		71
5		1100		0 64		704
6	1000	100	0.61	0.58	610	58
7		100		0.52		52
8		100		0.47		47
9		100		0.43		43
10		1100		0.39		429
11	1000	100	0.37	0.35	370	35
12		100		0.32		32
13		100		0.29		29
14		100		0.26		26
15		1100		0.24		264
16	1000	100	0.22	0.21	220	21
17		100		0.19		19
18		100		0.17		17
19		100		0.16		16
20		1100		0.14		154
		etc.....etc.				
(Approximate) total present worths					$2200	$2276

To agree with the classical approach, this calculation would be continued until the present worth figures became unmeasurably small. This yardstick says that *if the cost of money is 10%*, the proposed investment would be $2276–$2200 or $76 better than not making the investment. If the stipulated interest rate chosen happened to be 11%, the two present worth figures would have come out the same—because this is the rate of return of the project.

Time Adjusted Average Annual Cost Method

This method merely expresses both investment and income as equal annual equivalent expenditures. Calculations may be illustrated by application of the method to the same proposal evaluated above and by the P.I. in Fig. 1, assuming a stipulated rate of 10%.

Year	Investment	Receipts	10% Present worth factors—At an instant	10% Present worth factors—During year	Present worth amounts—Investment	Present worth amounts—Receipts
1	$1000	$100	1.00	0.95	$1000	$95
2		100		0.86		86
3		100		0.78		78
4		100		0.71		71
5		1100		0.64		704
				3.94	$1000	$1034

The total present worth of the investment and the income streams can now be expressed in terms of equal annual equivalents:

$$\$1034 \times \frac{1}{3.94} = \$263 \text{ per year}$$

$$\$1000 \times \frac{1}{3.94} = 254 \text{ per year}$$

Difference = $ 9 per year (Annual advantage at stipulated rate of 10%)

If the stipulated rate had been 11%, the true rate of return of the project, the difference would have been zero.

It seems to me that the foregoing adequately demonstrates the validity of the statement that these two methods are merely variations of the rate of return method and that the evaluation is in less usable form.

ADVANTAGES OF THE PROFITABILITY INDEX

The profitability index (and other similar yardsticks) has several very specific and important advantages:

1. It appears to have almost universal applicability. Nearly any true investment situation can be directly evaluated. With minor modifications in the way the problem is set up, it can handle all true investment evaluations.

2. The yardstick is a "rate" rather than an absolute value. For this reason it yields figures for individual proposals that are directly comparable regardless of variations in size or length of life of said proposals; yet the effect of these factors enters the calculations.

3. It is not necessary to make any prior assumptions regarding earning rates, cost of obtaining funds, etc. The earning rate is calculated. The yardstick obtained is independent of the "cost of capital" but can be directly compared with same. Identical projects will be identically evaluated regardless of the financial situation of the sponsor. This evaluation can then be directly adjusted for the financial situation of the sponsor.

4. It is sufficiently flexible to permit rapid, easy evaluation of simple projects; yet provides means for taking into consideration all necessary factors considered desirable in evaluation of large complex proposals and delivers in both cases figures which are directly comparable.

5. It provides the basis for and an extremely effective means of post audit. We can use it to find out:

(a) How accurate our specific predictions of expenditures and receipts were and, in this way, improve our "batting average" on future predictions.

(b) How well the project as a whole is performing in comparison with our original evaluation.

Presented at the Fourteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Pittsburgh, Pa., Oct. 12–15, 1959.

PUSEY & JONES ACQUIRED BY

Inglis

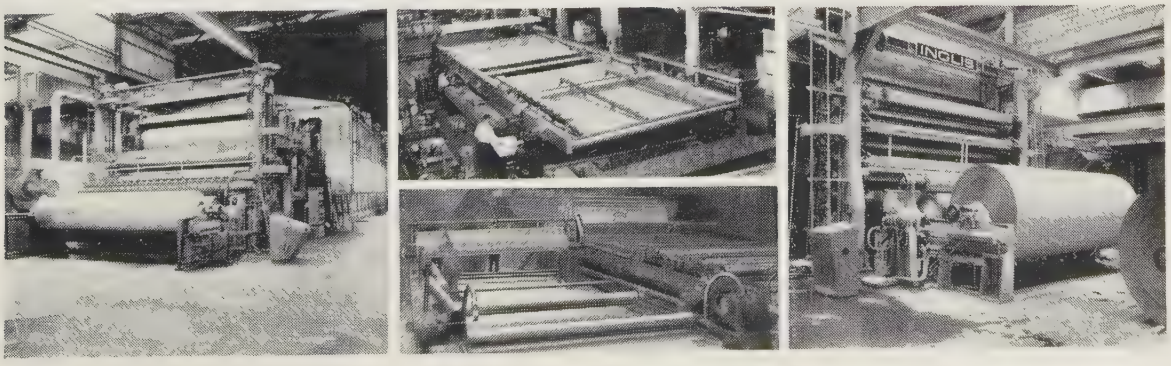
John Inglis Co. Limited, of Toronto, Canada, has purchased the assets of the Pusey & Jones Corporation, paper machinery manufacturers of Wilmington, Delaware. These assets include patents, trade-marks, the right to use trade name "Pusey & Jones", drawings, patterns, tooling, jigs and fixtures, inventories, work-in-process, the widely known Pusey & Jones Plastometer—in fact all assets other than real estate, buildings and machinery.

The John Inglis Company has manufactured pulp and paper machinery for many years, and since 1945 has been associated with the Pusey & Jones Corporation, building paper machines and components in Canada to the Pusey & Jones designs.

With the acquisition of these assets, Inglis is in a position to supply not only new machines, rebuilds, components, etc., but to supply service and spare parts to all customers of Pusey & Jones in all parts of the world.

Enquiries should be directed to John Inglis Co. Limited, 14 Strachan Avenue, Toronto, to the attention of Mr. K. S. LeBaron.

JOHN INGLIS CO. LIMITED 14 Strachan Avenue, **TORONTO, CANADA**



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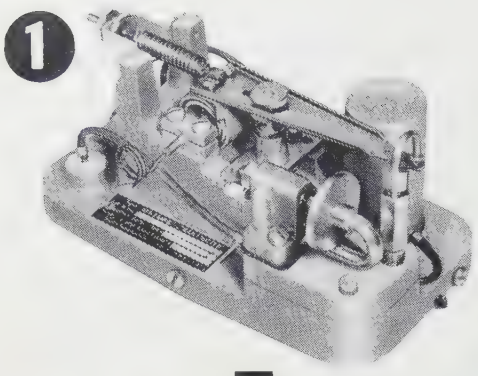
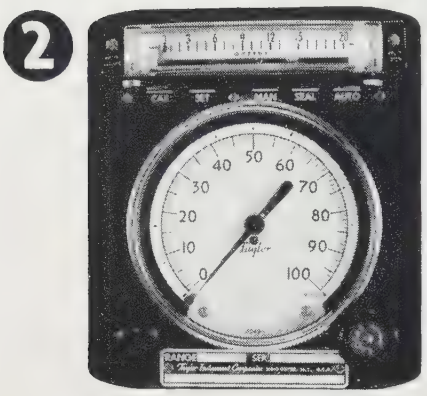
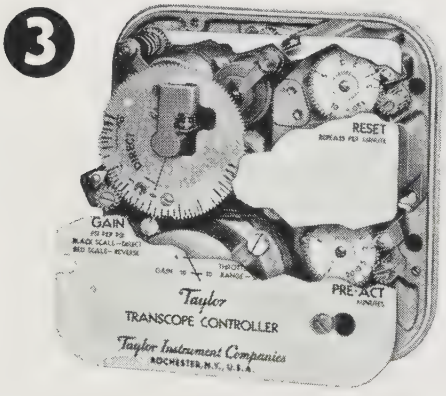
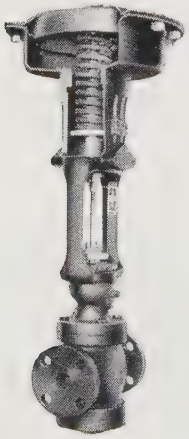








Taylor gives you the answer to temperature control that's

LOW ON COST

HIGH ON QUALITY!

The instruments shown here, all thoroughly field-tested and proven, combine Taylor dependability and accuracy with low initial cost. They're ideal for applications such as:

- Temperature control for Bleach Plant Mixers
- Brown stock washers
- Tower interface level
- For any application where a record of temperature measurement is not important

1 **Taylor SENSAIRE* Pneumatic Temperature Transmitter** operates within limits of minus 30°F. to plus 1200°F. with simplified adjustments, excellent repeatability and unusually fast response. Range spans of 50°, 100°, 200° and 400°F. Sturdy, compact, force-balance, mercury-filled thermal system, temperature compensated. Accurate to well within 1% of rated range below 550°F.; 1½% above 550°F. Ask for **Bulletin 98293.**

2 **Taylor TRANSET* Indicator** permits plug-in mounting of miniature Controllers. Exceptionally stable and drift-free set point adjustment, insuring stable output even with wide temperature variations. Continuous valve output. Simple automatic-to-manual switching. Maintenance and servicing is simplified by snap-in indicator gage, easily removed without disturbing piping or process control. Ask for **Bulletin 98097-K.**

3 **Taylor TRANSCOPE* Controller** is exceptionally sturdy and adaptable. It will stand up to vibration, rough handling in shipment or mechanical abuse in service and maintain its repeatability under widely varying ambient temperature conditions. Can be quickly adapted to changes in operating conditions or processing requirements. Response to adjustments is extremely fast. Motion-balance design simplifies maintenance. Ask for **Bulletin 98278.**

4 **Taylor LIN-E-AIRE* Valve Actuator** sets new standard in precision control. Has greater power, size for size; constant diaphragm area for improved control; precision alignment for friction-free stroking. Strength of drawn steel diaphragm case permits high pressure operation. New design gives long stroke with constant areas. Nylon-reinforced Buna-N diaphragm with rolling action insures long life and low hysteresis. Ask for **Bulletin 98316.**

Ask your Taylor Field Engineer for more details. Or write for appropriate Bulletin. Taylor Instrument Companies, Rochester, New York or Toronto, Ont.

*Trade-Mark

Taylor Instruments **MEAN ACCURACY FIRST**

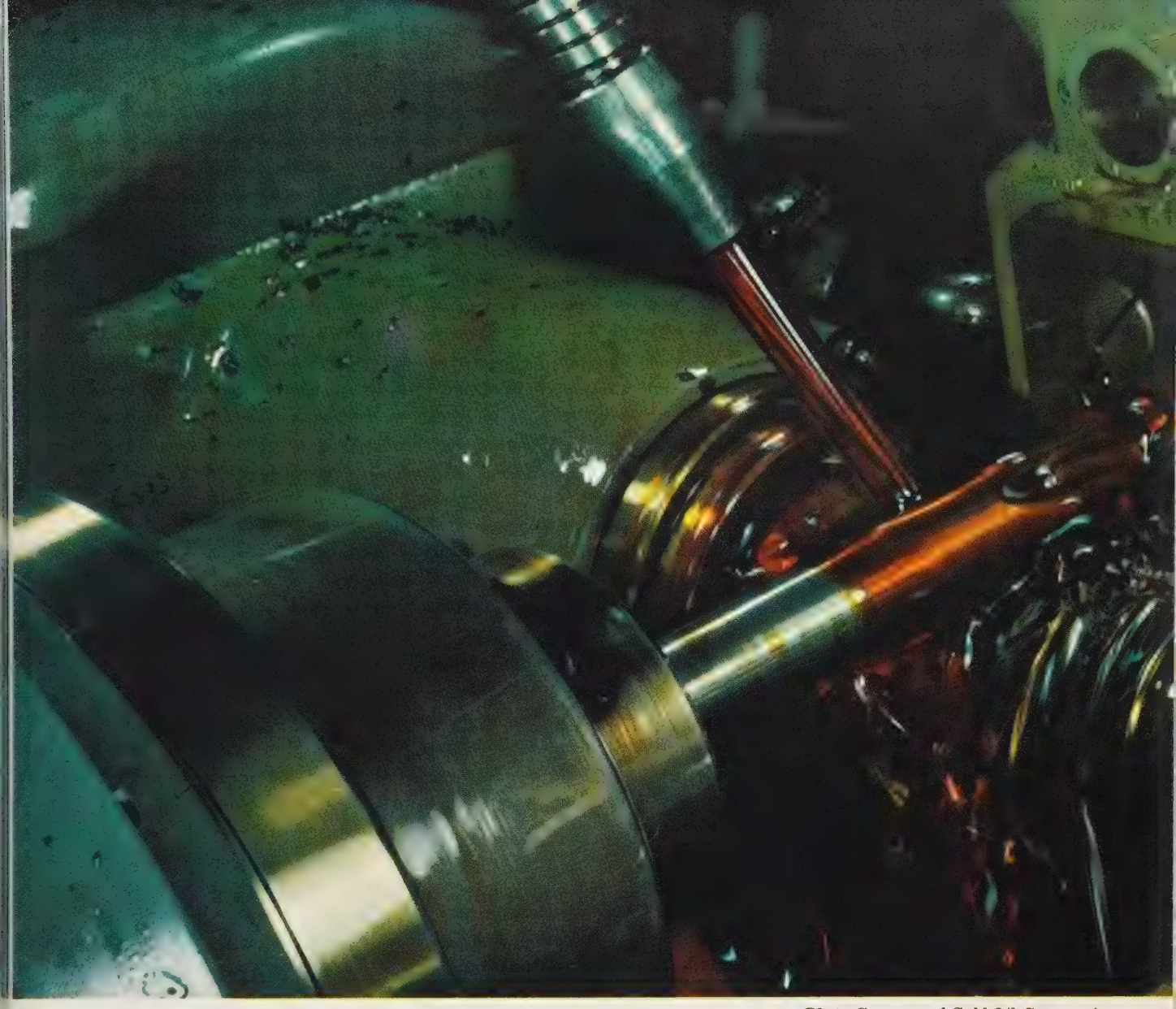


Photo Courtesy of Gulf Oil Corporation

Gleaming Offset...on RHOPLEX-coated stock

This page was prepared for quality offset printing with a coating using a RHOPLEX 100%-acrylic emulsion binder. As a result, the surface is uniformly smooth. Halftone dots reproduce sharply, and colors print with superlative brilliance and fidelity.

RHOPLEX emulsions are excellent binders for coating not only paper, but paperboard as well. In fact, the excellent results produced by RHOPLEX coatings on both bleached and unbleached kraft board have been a boon to package design. The superb printing qualities conferred by RHOPLEX emulsions spark up colored printing on cartons for cigarets, beverages, frozen foods, and cosmetics. In coating paperboard, the low viscosity of RHOPLEX coatings permits coating application at exceptionally high solids, for maximum whiteness and hiding power. Other advantages include excellent flexibility of the dried coating, outstanding water resistance, calenderability at lower-than-average pressures, and very good adhesion. Write for our 16-page booklet "RHOPLEX Acrylic Emulsions in Paper Coatings" for formulating information and technical data on RHOPLEX B-15 and RHOPLEX B-60A coatings for printing papers and paperboard.

RHOPLEX *is a trademark, Reg. U.S. Pat. Off. and in principal foreign countries.*

Chemicals for Industry

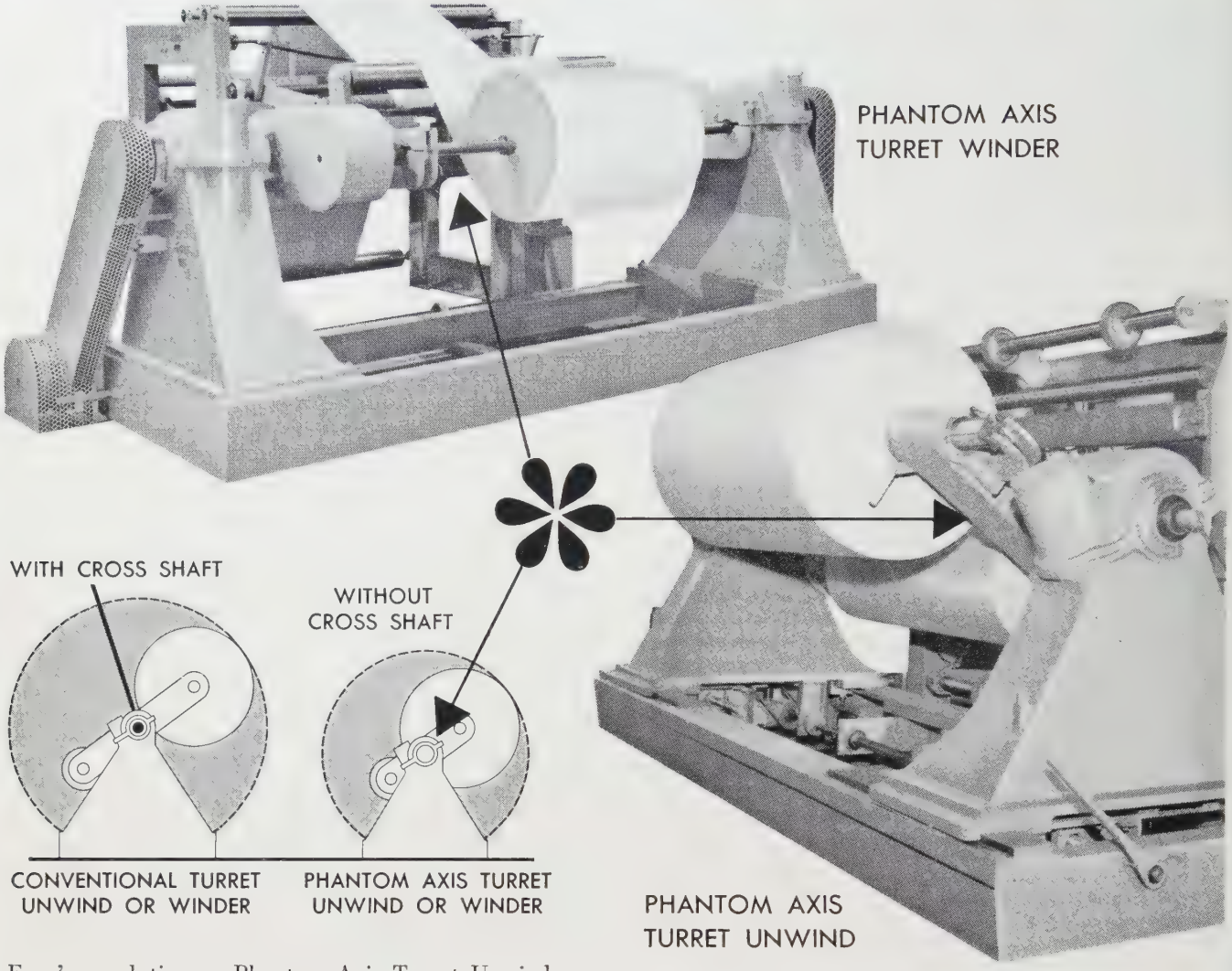
ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION

Washington Square, Philadelphia 5, Pa.

RHOPLEX

IT'S WHAT'S NOT THERE THAT COUNTS*



Egan's revolutionary Phantom Axis Turret Unwinds and Winders *eliminate* the center cross shaft for greater roll diameters and more compact overall design. In addition, these units require less overhead and floor space for installation (see drawing).

The more compact design also assures greater rigidity and better operation at high speeds. Phantom Axis Unwinds and Winders are engineered to permit speeds in excess of 1000 fpm; are available in web widths through 120", and include power rotation of the turret and knife cut-off as standard features. Air chucking of cores or shafts is available at the customer's option.

ADDITIONAL FEATURES

PHANTOM AXIS UNWIND: Automatic or manual side shifting; provision for splicing with either inside or outside of web up (optional); flying splices at full machine speed; pneumatic constant tension system (optional).

PHANTOM AXIS WINDER: Side shifting available (automatic or manual); constant or tapered tension; smooth transfers at full machine speed with unique single motor design.

Egan

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FRANK W. EGAN & COMPANY
SOMERVILLE, NEW JERSEY

MANUFACTURERS OF PROCESSING MACHINERY FOR PAPER, FILM & FOIL, AIR DRYING SYSTEMS; ROTOGRAVURE PRINTING PRESSES; PLASTICS EXTRUDERS & ACCESSORIES; TEXTILE FINISHING MACHINERY.

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Here's Why EC&M Pushbutton Automatic Starters Do The Job Better...

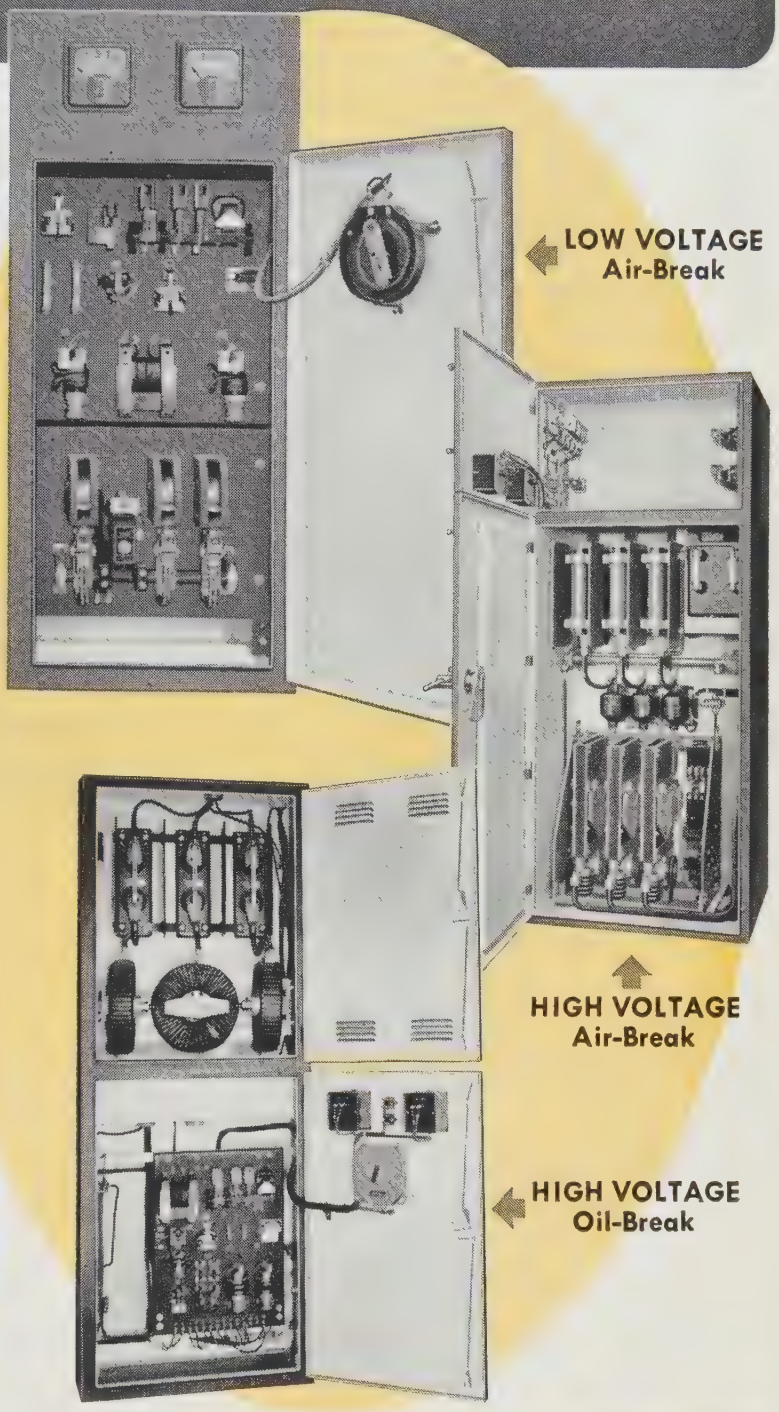
Complete protection during starting, acceleration and while running at synchronous speed.

Motor pulls into step without delay because field is applied under best conditions for synchronization.

Automatic field removal and re-synchronization allow motor to accelerate and re-synchronize after voltage dip or momentary overload.

Easily installed because all internal wiring is complete.

Full or reduced voltage starting All high voltage starters available in 3 ratings: (*1*) 50,000 KVA (certified) interrupting capacity—(*2*) with power-type, current-limiting fuses—(*3*) VALIMITOR® (volt-ampere-limitor), the bus may be of unlimited KVA.



Write for Bulletins 8200 and 8820

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8587

Non-staining blond laminated Thilco Tuf by Thilmany Pulp & Paper Co., Kaukauna, Wisconsin

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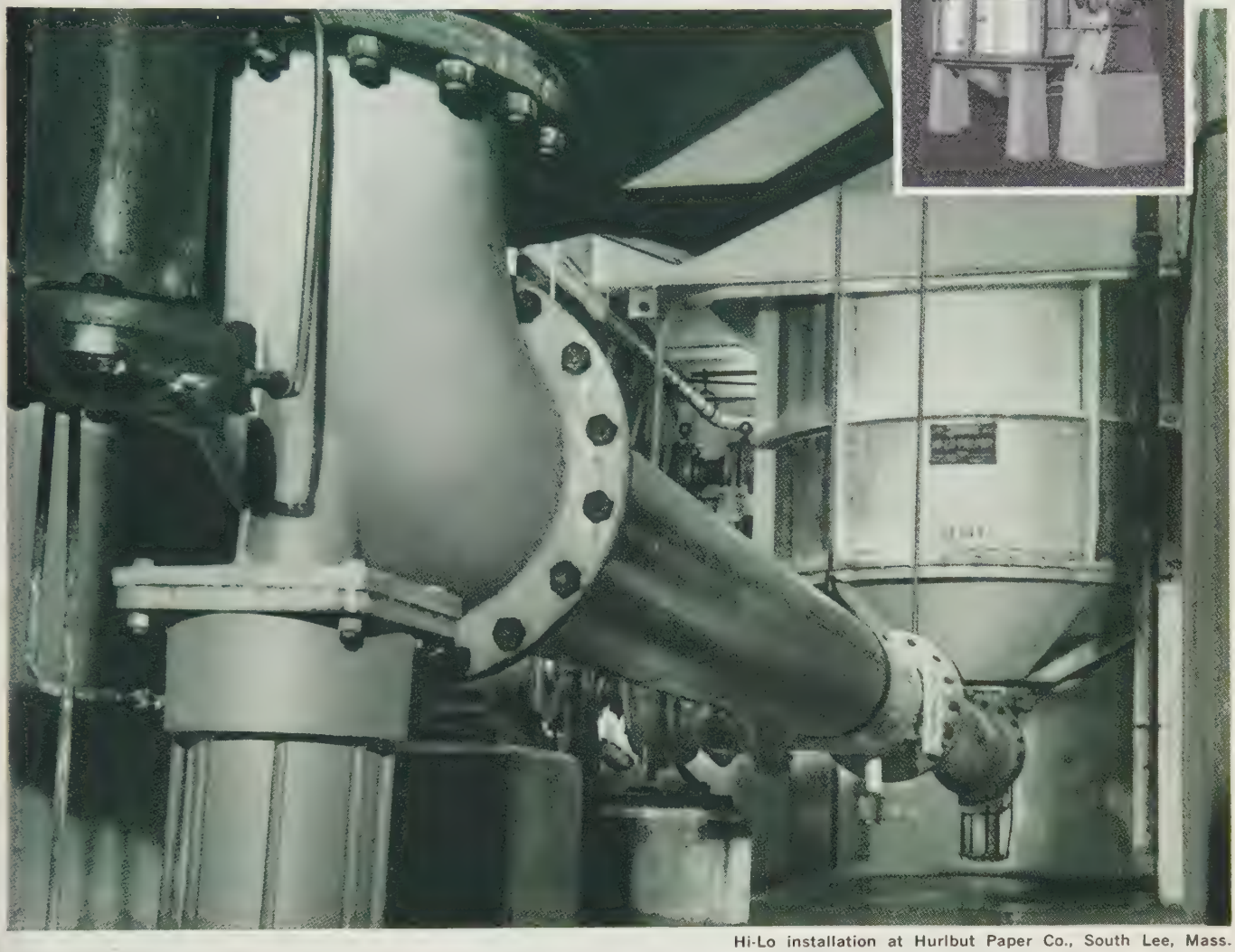
Jones Hi-Lo Pulper at Hurlbut Paper gives

TOP PERFORMANCE ON TOUGH WET STRENGTH



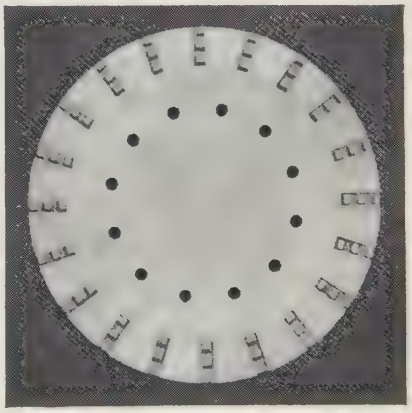
Hi-Lo installation at Hurlbut Paper Co., South Lee, Mass.

Defibers completely with minimum power

At Hurlbut, as in dozens of other mills across the country, the two-rotor Jones Hi-Lo Pulper has proven its ability to provide fast, progressive disintegration at low H.P. days per ton. It is especially effective on wet strength and other hard-to-defiber materials.

The Lo-Speed rotor breaks up the broke or bales economically and circulates the stock across the tank where repeated impacts by the Hi-Speed rotor complete defiberization. Blade construction prevents fiber cutting and freeness drop is eliminated.

For maximum performance with minimum power and maintenance, get full information on the Jones Hi-Lo Pulper. Write for bulletin EDJ-1063B.



Notched blades of Hi-Speed rotor project only ¼", use power most efficiently for defibering. Held securely by Duroid wedges, they can be replaced easily and inexpensively.

E. D. JONES CORP. PITTSFIELD, MASS. member BELOIT group

Jones

PULP MILL EQUIPMENT AND STOCK PREPARATION MACHINERY

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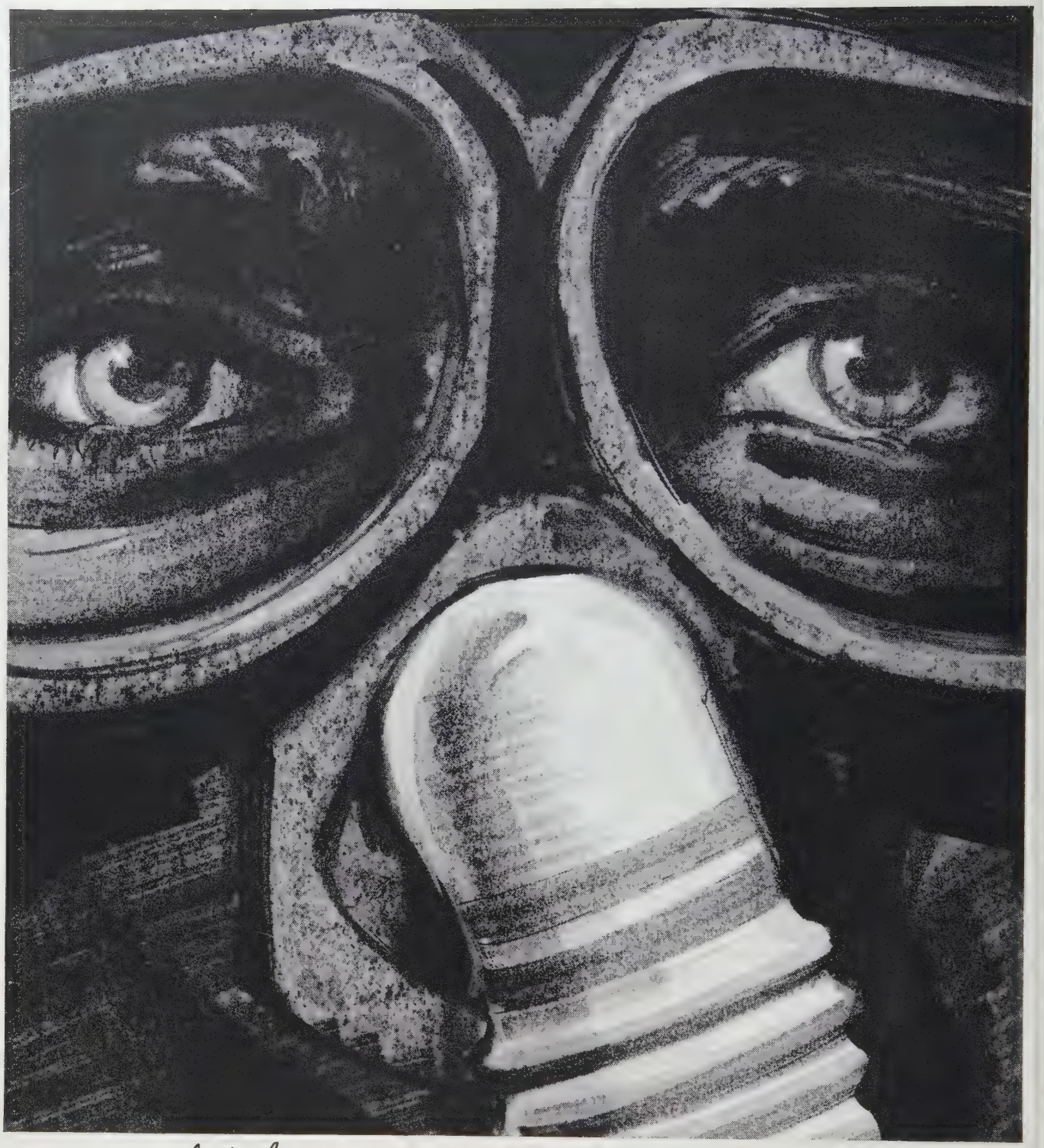
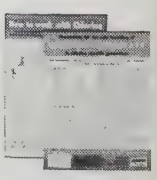


what have we done for you lately?

WHEN YOU HAVE A PROBLEM WITH PULP CHEMICALS, WE CAN HELP. WITH SAFETY PROGRAMS, FOR EXAMPLE.

We can instruct your personnel in accepted methods for handling such chemicals as caustic soda, chlorine, sodium chlorate, chlorine dioxide, etc. We can also offer safety lectures, along with suggestions for planning emergency programs for your mill. We also provide many pieces of literature on the subject. Just ask.



These wall charts on chlorine and sodium chlorate are examples of our safety program aids. Charts can be posted at or near the point of use. They list precautions to be observed in handling chlorine in all types of containers and sodium chlorate in tank cars. Write for your copies.

HOOKER CHEMICAL CORPORATION
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OTHER ALBANY FELT SERVICES DESIGNED TO HELP YOU!

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- Information Services:
  - Felt Facts
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  - Technical Films
  - Improved Felt Performance Book

Albany Felt Service Engineers are available to you to help solve your most difficult production problems.

All these men are highly trained and skilled in their profession. All have gained many years of experience in their analyses of a multitude of papermaking problems in mills all over the country. Most are graduates of paper mill schools and have held important positions in the mills themselves.

Their knowledge can be helpful to you, too, in your felt applications and in correcting other machine problems affecting maximum production.

TALK IT OVER WITH YOUR ALBANY FELT SALES ENGINEER

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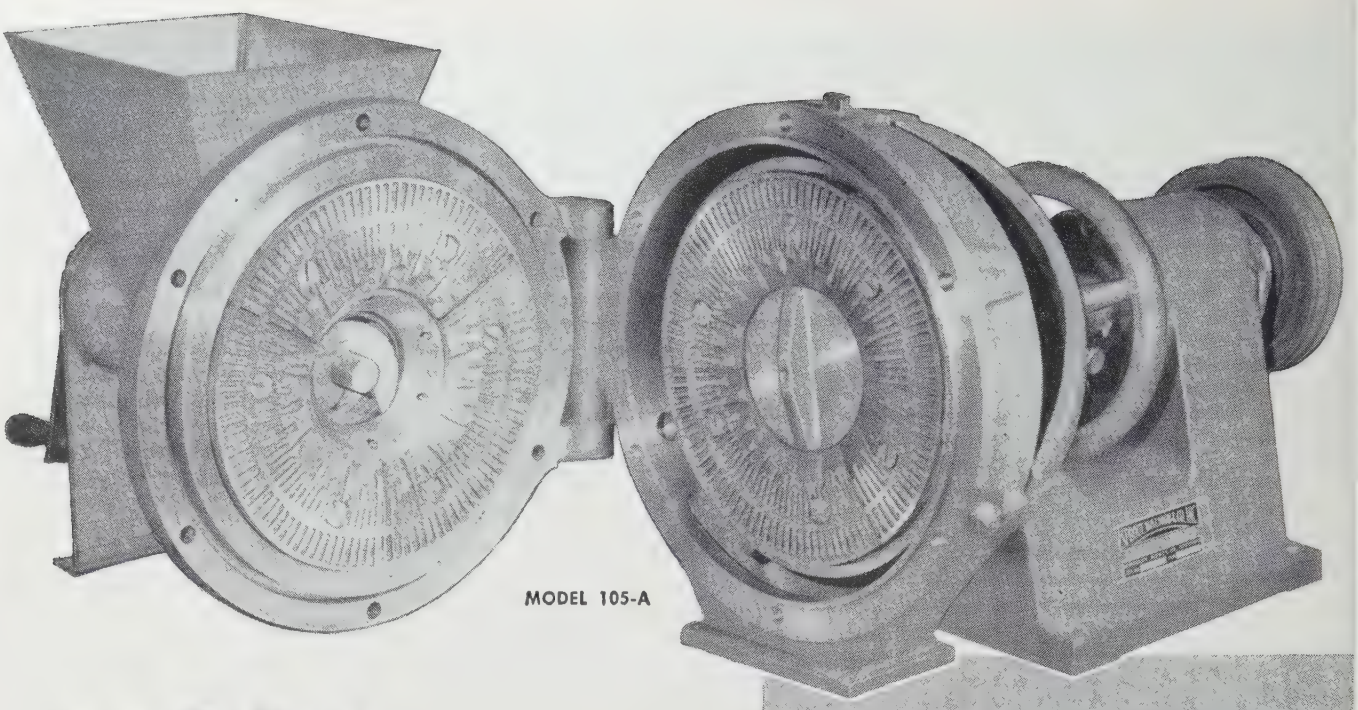
The World's Largest Manufacturer of Paper Machine Felts



MODEL 105-A

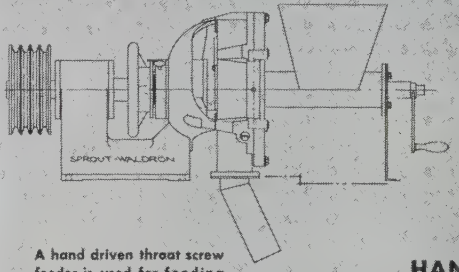
NEW "SPROUT" LABORATORY REFINER

Here is a precision-built machine design which simulates commercial refiner operations, saving valuable manhours and eliminating costly installation errors.

This 12″ single rotating disc laboratory refiner has the same mechanical features and plate designs used in the famous 36-2 "Sprout". Construction is rugged, dust-tight, water-tight and planned to permit easy access for plate changing. Simplified tramming makes it possible to maintain perfect parallelism of the disc, thus insuring uniform refining of the feedstock and even plate wear.

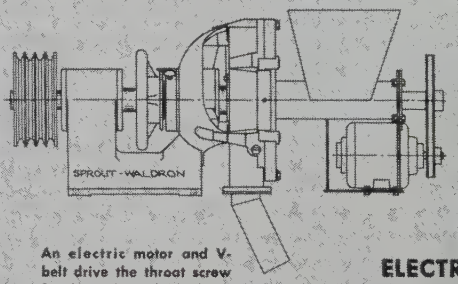
This "Sprout" lab refiner is available in cast iron or acid-resistant construction. It is suitable for continuous operation at horsepowers between 25 and 40. For intermittent operation, maximum horsepower may be increased to 65.

Specifications and details are covered in Bulletin 17-B. Copies available on request.



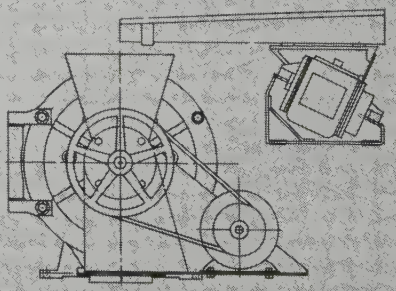
A hand driven throat screw feeder is used for feeding most materials in laboratory work.

HAND FEEDING



An electric motor and V-belt drive the throat screw feeder where fairly long runs are necessary.

ELECTRIC FEEDING



A magnetic vibratory feeder supplies a constant accurate flow of material.

MAGNETIC FEEDING

Feeding Arrangements MODEL 105-A

SPROUT, WALDRON & CO., INC.
PULP AND PAPER MILL DIVISION
MUNCY, PENNSYLVANIA, U. S. A.

REFINERS • CONVEYORS • FEEDERS • FIBER PRESSES
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E/206

62 A

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MIRACEL
CHLORINE DIOXIDE BLEACHED SOFTWOOD

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CHLORINE DIOXIDE BLEACHED HARDWOOD

PREHYDRATED
to facilitate blending with other fibers

AND NOW THERE ARE FOUR

Balanced Paper-Grade Pulps . . . Created by Papermakers for Papermakers

ALBACEL • ASTRACEL • MIRACEL • HYDRACEL

Throughout the free world, papermakers use and like Riegel Pulps . . .
paper-grade pulps that provide the right balance of all important qualities
. . . brightness, cleanliness, strength, formability and proper beating characteristics.
To increase the versatility and economy of our pulps, we have developed
two new grades, Miracel and Hydracel. These retain all the fine characteristics
of Albacel and Astracel . . . and in addition, have been prehydrated
to facilitate blending with other fibers.

RIEGEL PAPER CORPORATION
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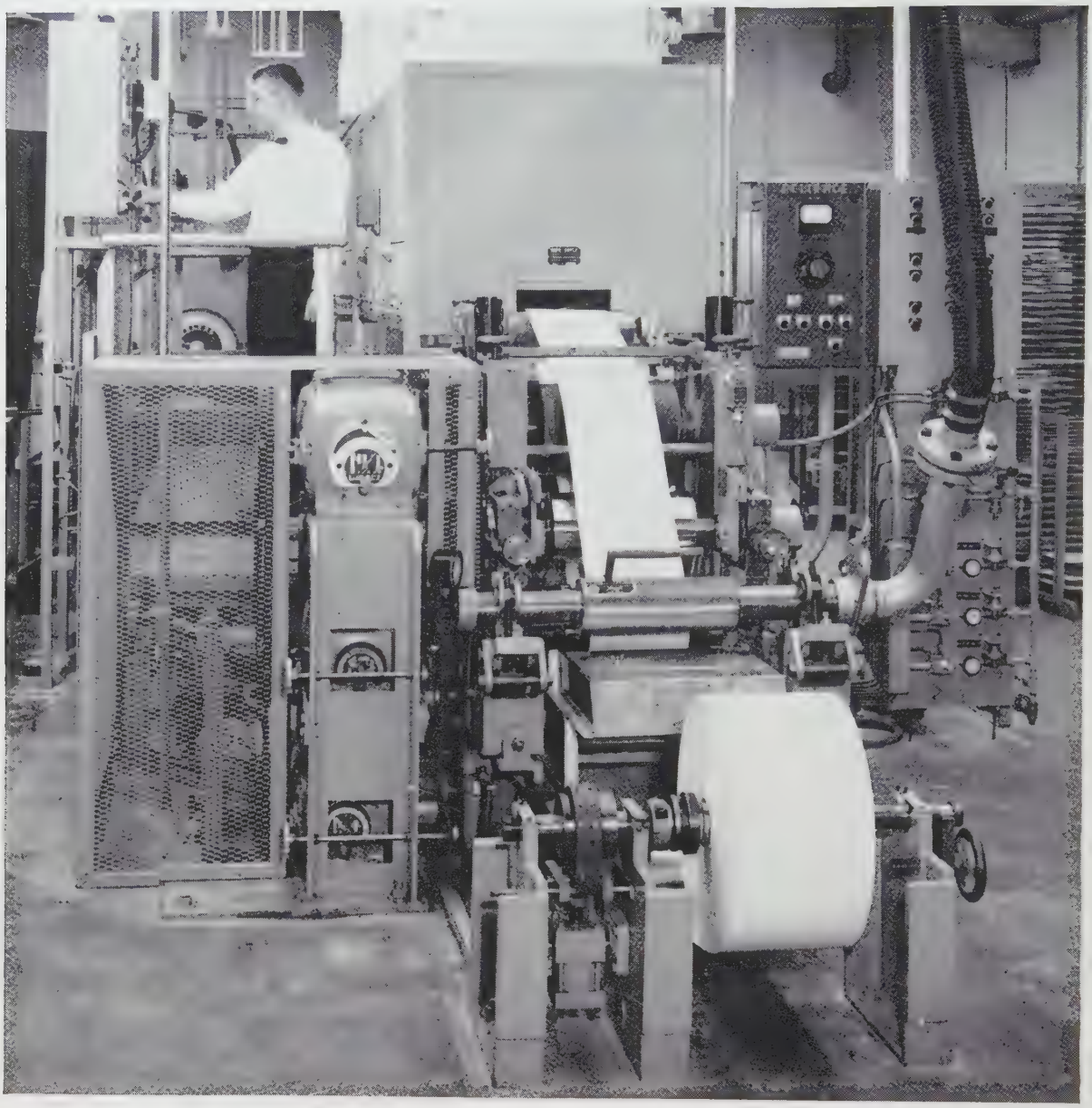
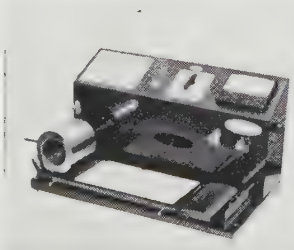
Du Pont announces an exclusive



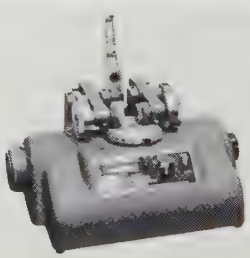
• Du Pont paper coater can simulate roll coating, air knife and trailing blade operations at speeds up to 750 ft./min. and can dry at speeds up to 500 ft./min.

Precision testing equipment used in the Du Pont Sales Technical Laboratory

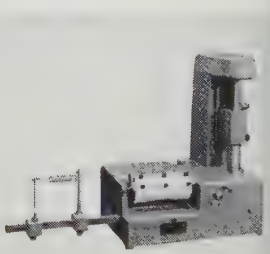


ABSORPTION TESTER

PRINTABILITY TESTER



ABRASER



VISCOSIMETER

Other testing equipment available: Laboratory Air Knife Coater • Burst Tester • Laboratory Coater • Bench Scale Trailing Blade Coater • Endurance Tester • Scrigraph • Tearing Tester • Stiffness Tester • Gloss Meter • Brightness Meter

ervice for the paper industry

Now... Du Pont service includes new laboratory equipment that can coat and test your paper to show you how "Elvanol" (polyvinyl alcohol) and "Elvacet" can improve product quality (polyvinyl acetate emulsion)

Now: a demonstration of performance you can measure . . . production advantages you can see, *before* you spend time and money making trial runs at your plant. By using a new, specially designed paper coater and precision testing equipment, Du Pont can show you how "Elvanol" and "Elvacet" can improve your paper quality and help you solve your coating and sizing problems.

Using your own paper, Du Pont's new laboratory paper coater (at left) can simulate most commercial coating operations. The precision testing equipment (see left) is then available to test performance and quality.

You'll save time and money by letting Du Pont coat and test *your* paper using their specially designed laboratory equipment. In this way, the advantages of "Elvanol" and "Elvacet" can be proven without interrupting your production schedule.

You are invited to take advantage of this *exclusive* service. Just get in touch with your nearest Du Pont representative (see district office list below). He'll make prompt arrangements to have your paper coated and tested at Du Pont's Sales Technical Laboratory and show you how "Elvanol" and "Elvacet" can profitably fit into your business.

ELVANOL® (polyvinyl alcohol) ELVACET® (polyvinyl acetate emulsion)

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BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

You can use Du Pont "Elvanol" and "Elvacet":

TO PRODUCE:

Grease-Resistant Coatings
Release Coatings
Wax-Barrier Coatings
Solvent or Lacquer Holdout Coatings
Clay Coatings
Sizes for Gloss Ink Printing
General Surface Sizes

TO OBTAIN:

Improved IGT Pick
Curl Control
Reduced Cobb Size
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Improved Abrasion and Scuff Resistance

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We are sure you know about the high quality of Dryden Bleached Sulphate Pulp. But did you know that you can also make Dryden your single source of supply for many other kraft pulps?

Dryden Unbleached—widely recognized for its high tensile strength—for everything from twisting tissues to boxboards.

Dryden Electrical Pulps—tailor-made for cable wrap, transformer board and capacitor tissue.

Dryden's Other Specialties—formulated to meet many unusual requirements. (We produce pulps for anti-tarnish papers, for example.)

We would be glad to make up a single boxcar shipment of several of our pulps for you to try in your own operations.

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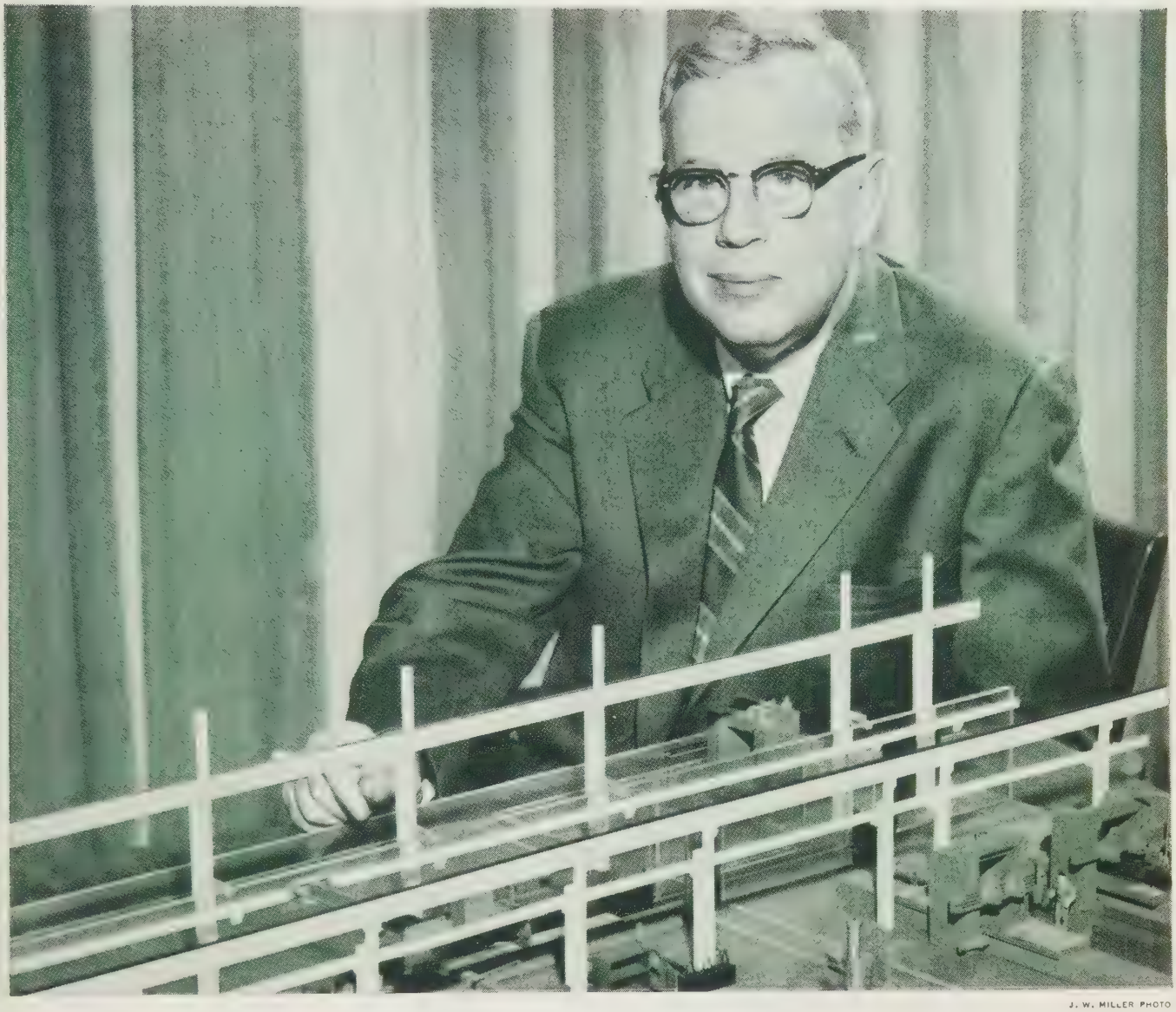


J. W. MILLER PHOTO

Beloit Eastern's Bill Wood

Looking over a model of the newly modernized shops at Downingtown, Pennsylvania, is Beloit Eastern Corporation's president, W. S. Wood. Bill and his staff are experts, not only in designing the finest equipment, but also in its meticulous founding and manufacture. Modern methods, increasing the plant's effectiveness as "your partner in paper-making," result in the finest of equipment designed and built for long, rugged, and dependable service. Call on us for your finished product processing equipment needs.

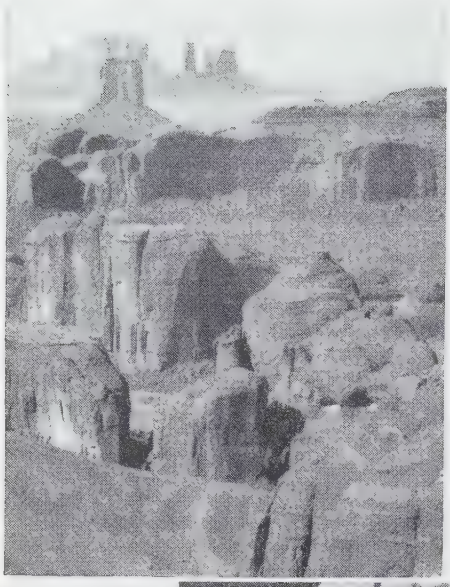
FINISHED PRODUCT PROCESSING EQUIPMENT

Winders • Petite Winders • Slitters Supercalenders • Roll Wrappers Roll Lowering Tables • Roll and Shaft Handling Equipment • Conveyors Unwind Stands and Tru-Tension Controls • and other equipment for the paper and allied industries.

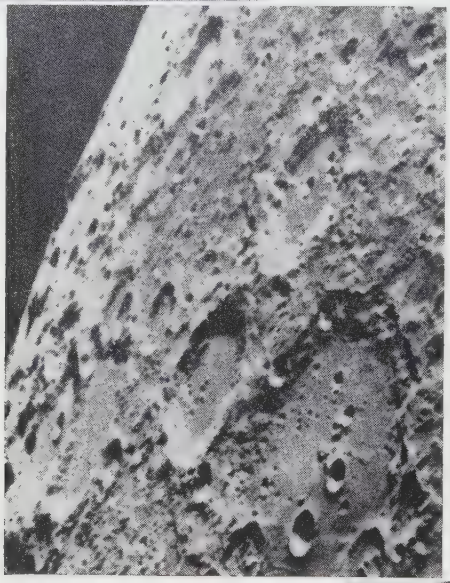
BELOIT EASTERN CORPORATION

DOWNINGTOWN, PENNSYLVANIA

Member Beloit Group



Hills and valleys may be beautiful...



Spotty surfaces interesting...

Foam fun...

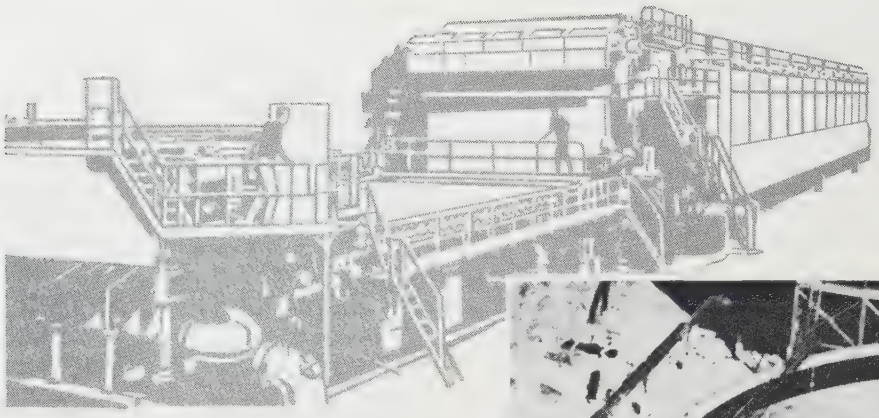
But not for paper coaters

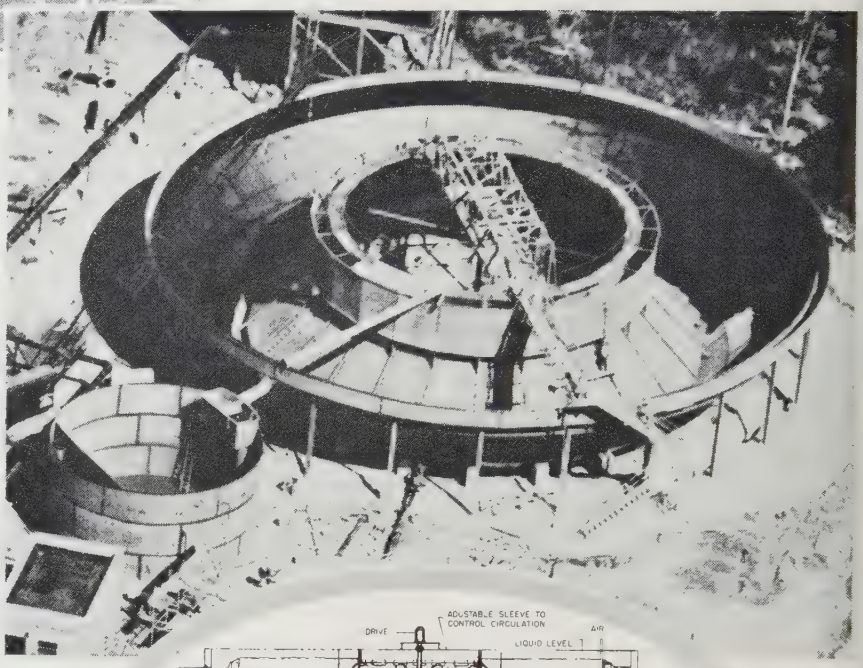
Solve three paper coating problems with one new formula—DYLEX® K-54 latex. DYLEX coatings give better smoothness, higher pick resistance at all adhesive levels, and less foam. These are not just *claims*. Intensive tests conducted by Koppers and by leading paper mills, prove that DYLEX K-54 is a *superior* latex coating.

In addition to DYLEX K-54, Koppers research has also developed DYLEX K-52, for conventional clay coatings, and DYLEX K-85, for specialty papers requiring an extremely high gloss. Koppers is continuing intensive research to develop new and better styrene-butadiene latices for the paper industry.

For more information on how these latices can improve your paper coatings, write Koppers Company, Inc., Plastics Division, Pittsburgh 19, Pennsylvania.

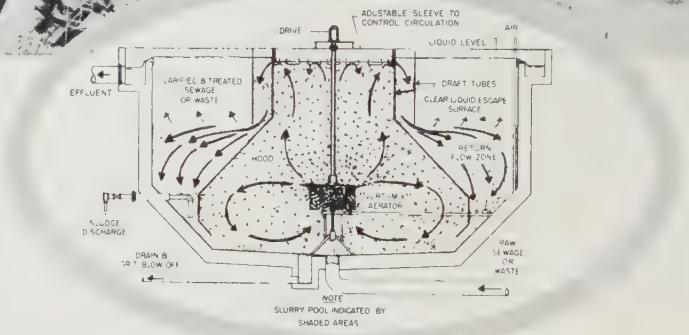
KOPPERS PLASTICS





AERO-ACCELATOR®

Activated Sludge Plant for Mill Effluent Treatment...



– 90% AND HIGHER B.O.D. REMOVALS!

– SPACE SAVINGS UP TO 50%!

– LOWEST INSTALLED COST!

The "AERO-ACCELATOR" plant offers a practical solution for complete treatment of your mill effluent.

Using the most modern biological and hydraulic principles, "AERO-ACCELATOR" activated sludge plants carry on high rate clarification together with biological oxidation of organic materials. They offer the additional advantages of efficient operation at high loadings, and stability under shock loads.

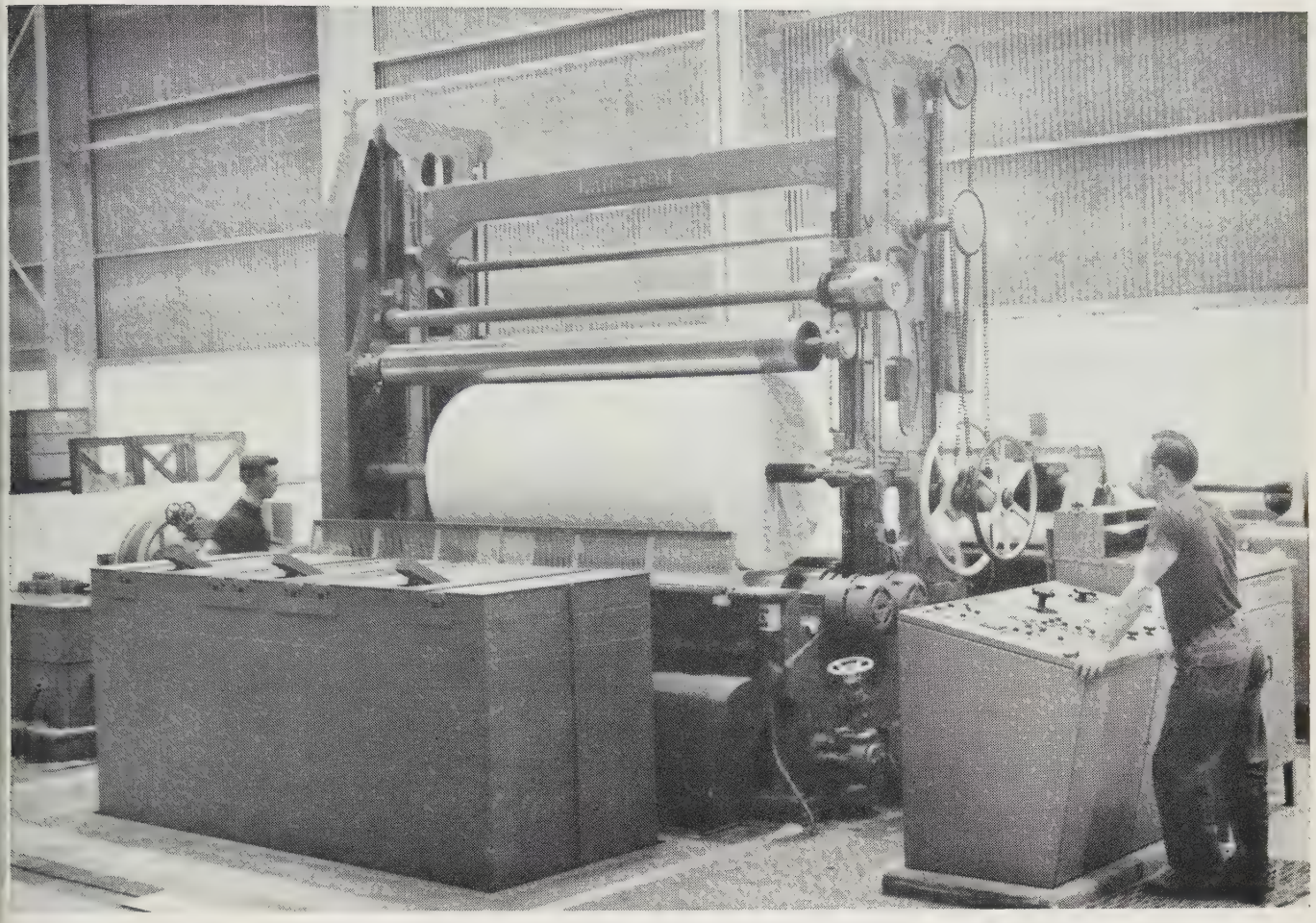
Bulletin 6510 will be sent on request.

Inquiries are also invited on all water and waste treatment problems in the pulp and paper industry.

INFILCO

INFILCO INC. • General Offices • Tucson, Arizona
Field offices throughout the United States and in foreign countries

6011



One of the two 104-in. Langston Slitters and Winders in the Glatfelter mill completing rewind. Roll drop table in foreground is up, ready to receive roll when ejected by the winder, and chocks are in raised position to stop the roll. Note console incorporating all major indicators and controls.

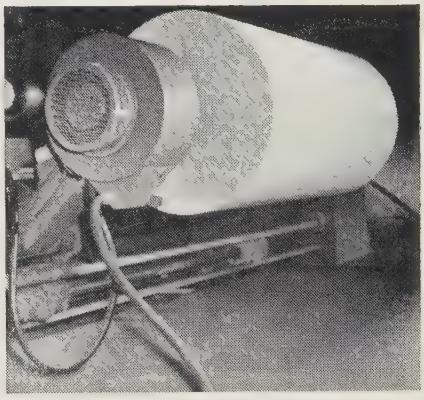
Langston Slitters and Winders turn out tight, even rolls at Glatfelter Mill

Two 104-in. Langston Slitters and Winders have been working in the new mill of P. H. Glatfelter Co., Spring Grove, Pa., for more than a year. They have proved themselves in round the clock production on grades from fine papers to book.

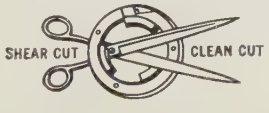
One of the most important features, according to the company, is the constant tension unwind control on the Langston Shaftless Roll Stand, which keeps the tension constant throughout the winding operation. Perfect rolls can be turned out from 9 to 100-lb. stock in roll widths from 7½ to 104 in.

The equipment can be quickly loaded and lined up on the back stand and is designed for easy threadup and gang slitter setting. Hydraulic roll ejectors move the finished rolls quickly from the winding position to the roll drop. Other features include shearcut slitters to eliminate dust; many interlocked controls for extra safety; automatic edge guide control to allow precision trim rewinding of narrow and salvage rolls.

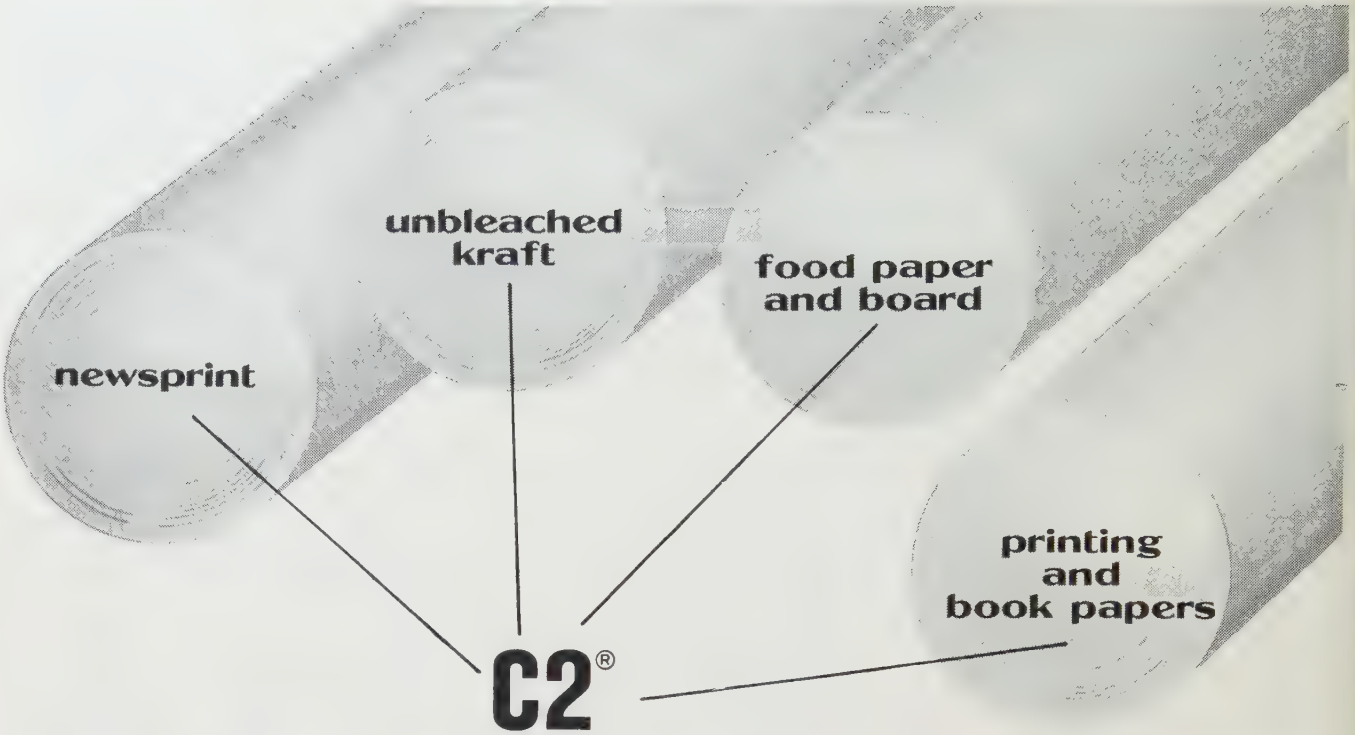
Find out how Langston Slitters and Rewinders can benefit you. Write SAMUEL M. LANGSTON Co., 6th & Jefferson Sts., Camden 4, N.J.



Langston Shaftless Unwind Stand eliminates back-breaking, time-consuming task of hoisting heavy shafts into place. Hydraulically operated arms reach out, pick up the roll, and raise it into running position—a 1-man, pushbutton operation.



LANGSTON Leadership...by design



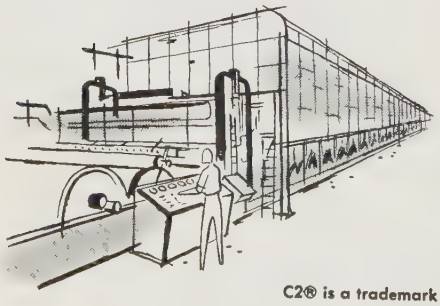
the new slimicide

★ **FDA approved**

★ **effective**

★ **easy-to-use**

★ **economical**



C2® is a trademark

Food and Drug Administration states that sodium chlorite slimicide is not a food additive in paper manufacture because it cannot become a component of food through this use. C2, of course, is the Olin Mathieson trademark for sodium chlorite slimicide.

Extensive experience in many mills demonstrates that C2 is an effective, low-cost slimicide for machines producing many types of paper including newsprint, unbleached kraft, food paper and board, and printing and book papers. No detrimental side effects have been observed.

C2 is readily soluble in water and is non-corrosive to equipment.

Average use level is 10 to 20 cents per ton of pulp. C2 is available in quantities ranging from one pound samples to 100 pound drums in truckloads and carloads. C2 also can be shipped as a 50% solution in tank cars or highway transports.

For assistance or further information, write the Sales Development Department, Baltimore 3, Md. Data sheet available upon request.

7755

CHEMICALS

Olin Mathieson

CHEMICALS DIVISION, BALTIMORE 3, MD.

THE MOST ECONOMICAL DIRECT YELLOW DYE!

Looking for the most economical, direct yellow dye available anywhere? Here it is! This paper is dyed with Du Pont Brilliant Paper Yellow. It's a direct yellow dye with very good lightfastness which shows a minimum of two-sidedness. You should consider it for all your high-grade stocks such as bonds, ledgers and covers, except where alkali fastness is important.

You can also use this color in formulations for canary, primrose, buff, cafe, goldenrod, india or grey and salmon shades. *Broke* dyed with it is bleachable and it shows *good* to *very good* solubility.

Even if Du Pont Brilliant Paper Yellow isn't what you're looking for, you'll probably find that Du Pont does have a yellow you *should* use. For information, write your nearest sales office, or see your Du Pont dye salesman.

QUALITIES YOU WANT IN A YELLOW DYE?	THEN TRY:
Alkali fastness plus most of the features of Du Pont Brilliant Paper Yellow	"Pontamine"* Yellow CHP
Bright and bleachable. Works without alum in unsized papers	"Pontamine" Bond Yellow CS or "Pontamine" Fast Yellow 4GL
Economical red shade of yellow with very good chlorine fastness	Du Pont Stilbene Yellow GX
Most economical yellow for unbleached pulp or groundwood—basic	Du Pont Auramine
Very bright canary shade yellow—economical and quite soluble	"Pontamine" Bond Canary G
Bright canary pigment—fast to water bleeding—a free-flowing liquid	"Lithosol"* Fast Yellow HV Paste
Exceptional chemical and lightfastness properties	"Pontamine" Fast Yellow BBL or "Pontamine" Fast Yellow NNL
Very good lightfastness and little two-sidedness—acid	Du Pont Quinoline Yellow
Soluble direct yellow good for both coating and general beater use	"Pontamine" Yellow SXG

*Reg. U. S. Pat. Off.

news from Du Pont

DU PONT MODERNIZES DYES & CHEMICALS TECHNICAL LABORATORY

The 40-year-old technical laboratory for Du Pont Dyes & Chemicals located at Deepwater Point, N. J., is growing younger every day. A 1½-million dollar renovation of the sales service and development facilities of the division's Technical Laboratory is well underway. This represents the first major expansion of the laboratory since 1936.

The expansion program will provide the most modern laboratory facilities for applications research in the division's original area of dyes. And it will answer the need for research and development facilities for industrial chemicals, many of which were introduced within the past decade.

Laboratory Director V. R. Hurka points out that "this modernization program will increase Du Pont customer service in the dyes and industrial chemicals field." He is enthusiastic about the program and notes that "new, modern equipment is essential in helping solve the many problems presented by consuming industries."

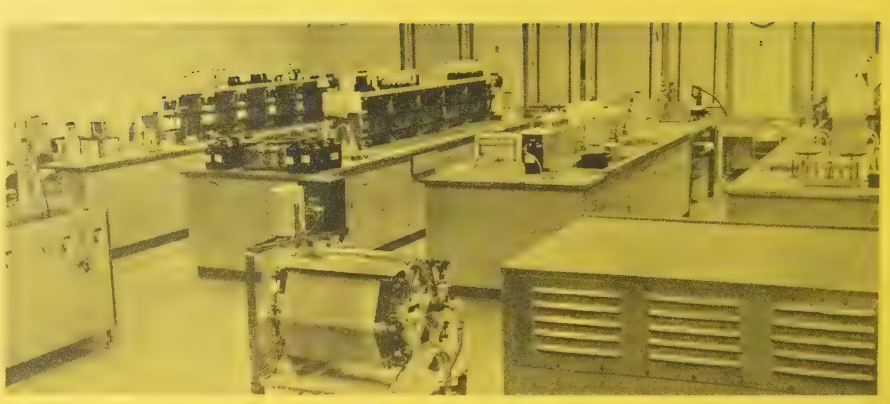
Already completed and in use is a new paper laboratory. This is where the division's scaled-down Fourdrinier paper-making machine is located.

The laboratory has been responsible for the development of a number of

(continued on other side)

new and improved processes. More than 10% of the people employed at the laboratory are technical experts in dyes and chemicals applications in the paper industry.

In addition, the laboratory supervises the division's quality control program, produces all of the division's technical literature and serves as an important training center for the sales and technical representatives of the Du Pont Dyes & Chemicals Division and its many customers.



news from Du Pont

NEW RESIN FINISH GIVES DUPLICATING PAPERS HARDER FINISH, REDUCES LINT...PICKING

"ZORON"* WS, a surface applied synthetic resin, can be used with starch to surface-size paper and give it a harder finish. This quality makes it excellent for duplicating paper, since it materially reduces the amount of lint on the paper. As a result, these papers are less likely to clog up duplicating machines.

"ZORON" WS doesn't require aging of solution, and it remains stable in solution for at least 48 hours at size tub temperatures. Conventional mill equipment can be used to apply it. It has been proved highly practical on the Fourdrinier paper-making machine in the Du Pont Paper Laboratory.

For more information about this resin and its application to duplicating paper, write to the Du Pont district office nearest you, or see your Du Pont salesman.

*Reg. U. S. Pat. Off.

WHAT'S YOUR PAPER PROBLEM?

Du Pont offers broad and diversified lines of chemicals for all types of papers.

Is your problem listed here? Check these items:	These, or related, chemicals and Du Pont experience could help you.
Bleaching	"Zepar"* BP reducing agent
Bleed Fastness Improvement	
Acid Dyes	"Insonite"* dye fixing agent
Basic Dyes	Du Pont Mordant BS
Curl Prevention	"Avitex"* Q softener "Avitex" ML softener
De-inking Assistance	"Alkanol" HCS surface active agent
Dye Fixing	Du Pont Mordant BS "Insonite" dye fixing agent
Dye Leveling	Du Pont Retarder LAN
Felt Washing	"Alkanol" HCS surface active agent "Duponol" RA surface active agent
Formation Improvement	"Avitex" MS softener "Avitex" Q softener
Graniting Prevention	Du Pont Retarder LAN
Linting Reduction on Printing Grades	"Zoron" WS
Pulping Assistance	"Alkanol" HCS surface active agent
Safety Paper Chlorine Indication	"Chlorostain"* N chlorine indicator
Softening	"Avitex" ML softener "Avitex" Q softener
Starch Insolubilization	"Zoron" WS resin finish
Wet Strength Imparting—surface application	"Zoron" WS resin finish

There's probably a Du Pont chemical that can help you. We offer a broad range of detergents, emulsifiers, resins, lubricants and specialty products such as water repellents, electrically-conductive chemicals, wetting agents, and many others. For complete data, write the district office nearest you.

DU PONT
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DYES AND CHEMICALS

Better Things for Better Living
. . . through Chemistry

E. I. du Pont de Nemours & Co. (Inc.)
Organic Chemicals Department
Dyes and Chemicals Division
Wilmington 98, Delaware

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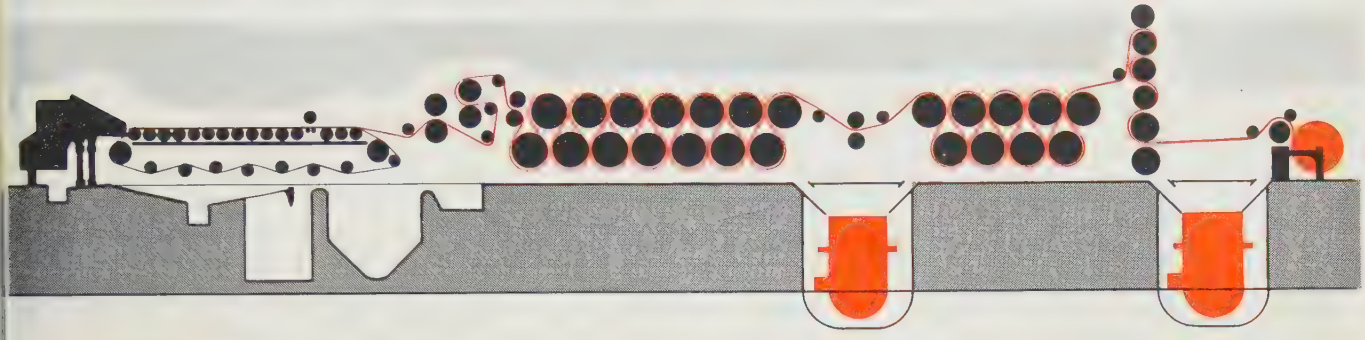
DU PONT OF CANADA LIMITED
Montreal, Canada

Morden-ize Your Mill

FOR GREATER EFFICIENCY, INCREASED TONNAGE



MORDEN "SLUSH-MAKER" FOR RECLAIMING MACHINE BROKE

Continuous double-rotor models available for wider and higher tonnage paper machines.

MORDEN "SLUSH-MAKER" pulping units are adaptable to a variety of steel, tile, or concrete tanks.

•

All installations individually engineered to customer specifications.

Continuous Pulping Operation—through automatic controls, handling all weights and grades of paper and board, at full machine production rate. In most applications NO separate broke refining necessary.

Wet-Strength Repulping and Defibering—with the efficient rotor blade-attritioning ring action—defibers *all* grades of wet strength in minimum time. Pulping efficiency data available on request.

MORDEN "Slush-Makers" are used in furnish make-up, broke reclaiming and deinking plants—either continuous or batch operation.

Avail your mill of the facilities and services of Morden—specialists in refining and pulping. Morden consultants and laboratory serve the paper industry the world over.

Around the world the Morden name stands for quality and service in stock preparation equipment.

ASK FOR information on Morden's complete line of refiners, jordans and pulpers. Learn how they can benefit your operation.

MORDEN
MACHINES COMPANY

3420 S. W. Macadam Avenue • Portland, Oregon

UNITED STATES REPRESENTATIVES: South: Brandon Sales, Inc., Greenville, South Carolina
Midwest: Dan B. Chapman, Appleton, Wis. • Northeast: Orton Corporation, Fitchburg, Mass.

Bigger Sales...

- No decrease in tensile strength
- Increased cross-directional tensile strength
- No effect on colors
- Rewetting properties are unaffected

Better Production...

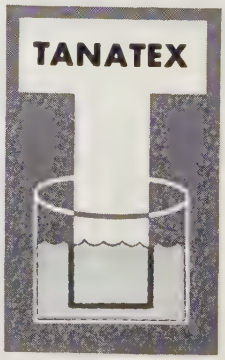
- Machine speeds maintained or increased
- Smoother running machines — less down time
- Will not yellow or develop odors on ageing
- Will not foam or froth in use

CELLOLUBE® Q-2

Quaternary Ammonium Paper Softener

Cellolube Q-2 softens napkins, tissue and towel stocks *without adverse effect on physical properties* — puts added "soft sell" in the finished product . . . without creating processing problems. And Cellolube Q-2 gives you wider latitude in pulp selection too! Sheets leave the doctor blade more uniformly, with a finer crepe. And machines actually run more smoothly with less down time. For a revelation in superior paper softening test Cellolube Q-2 now!

Economical Cellolube Q-2 treats tissue stock for as little as $1.33 per ton, and toweling for $3.30 per ton. Increased processing speeds may actually lower your over-all costs! Tanatex is prepared to demonstrate Cellolube Q-2 in your mill on a full scale trial. For details write, wire, phone:



TANATEX CHEMICAL CORPORATION

Belleville Turnpike, Kearny, New Jersey
WYman 8-0732

CHEMICALS
FOR DIFFICULT PROCESSING

NALCOAG® Adds ANTI-SLIP Features to Your Kraft, Boxes or Bags with Low-Cost 49-50% Colloidal Silica

Coating of Nalcoag Improves Load Stability, Reduces Slippage of Bags and Cartons During Shipping and Handling

Now you can add a *non-skid* feature, *another sales advantage*, to the paper and paperboard you make for use in shipping containers . . . and you can add it economically with low-cost Nalcoag colloidal silica.

Protect Products, People

Sliding boxes, bags and cartons are a dangerous and expensive problem. Damage to products during shipment is often traceable to slipping and sliding containers . . . and the possibility of falling bags and cartons is an ever present hazard to the men engaged in shipping, receiving and warehousing operations.

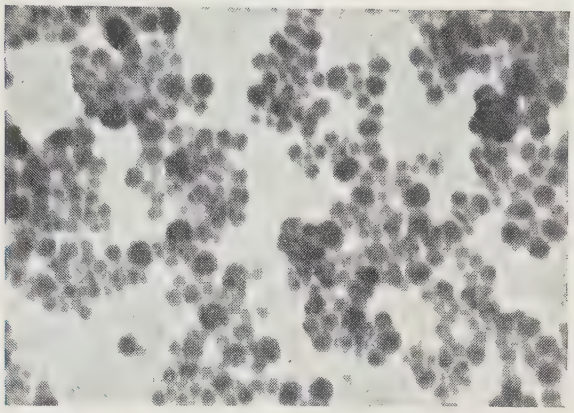
Nalcoag coatings create a frictionizing effect that greatly reduces the surface slippage. Bags and boxes stack higher with a far greater margin of safety . . . loaded forklifts travel faster, take steeper ramps and inclines with Nalco treated non-slip loads.

Improve Package Appearance

Even though a Nalcoag coating is invisible, it can produce visible improvements in containers. Treated bags and boxes have good soil resistance qualities . . . are cleaner, better looking on reaching destinations. And when a Nalcoag coating is applied *before* printing it has a sealing effect that reduces ink penetration, stops "feathering" and assures a sharper, cleaner package design that enhances customer appeal.

Economical, Easy-to-Apply

Effective frictionizing can be accomplished with very low dosages of Nalcoag. In some cases as little as 1/100 lb. of silica will treat 1000 square feet of paperboard, and seldom is more than 1/10 lb. required.



Silica particles in Nalcoag are so small they are hardly visible even in this photomicrograph at 65,000 magnifications. Nalcoag coatings on paperboard containers are not visible, but they create a powerful frictionizing effect on treated surfaces. Products packaged in bags or boxes are much safer during shipping, handling and stacking if the packages have a non-skid Nalcoag coating.

New Nalcoag 1050 gives you real economy in the highest silica concentration yet available . . . a highly stable, fluid, easy-to-use product of *49–50% silica!* It goes farther, lasts longer than the dilute 30% concentration now widely used . . . and it markedly reduces shipping, storage and handling costs.

Application of Nalcoag to sheet or board is relatively simple. Spraying, roller-coating and calender stack applications have all been used successfully and can be readily adapted to most mill operations.

Ask For Product Data, Technical Help

Nalco technical people are ready to help you make a better, safer, *non-skid* product. They will work with you *in your mill* . . . provide prompt, experienced assistance in establishing the best method of application and the optimum chemical dosage.

Product data on Nalcoag is ready for you, too. Why not write for it today . . . and ask us about *anti-slip* before your customers ask you!

NALCO CHEMICAL COMPANY
6197 West 66th Place • Chicago 38, Illinois

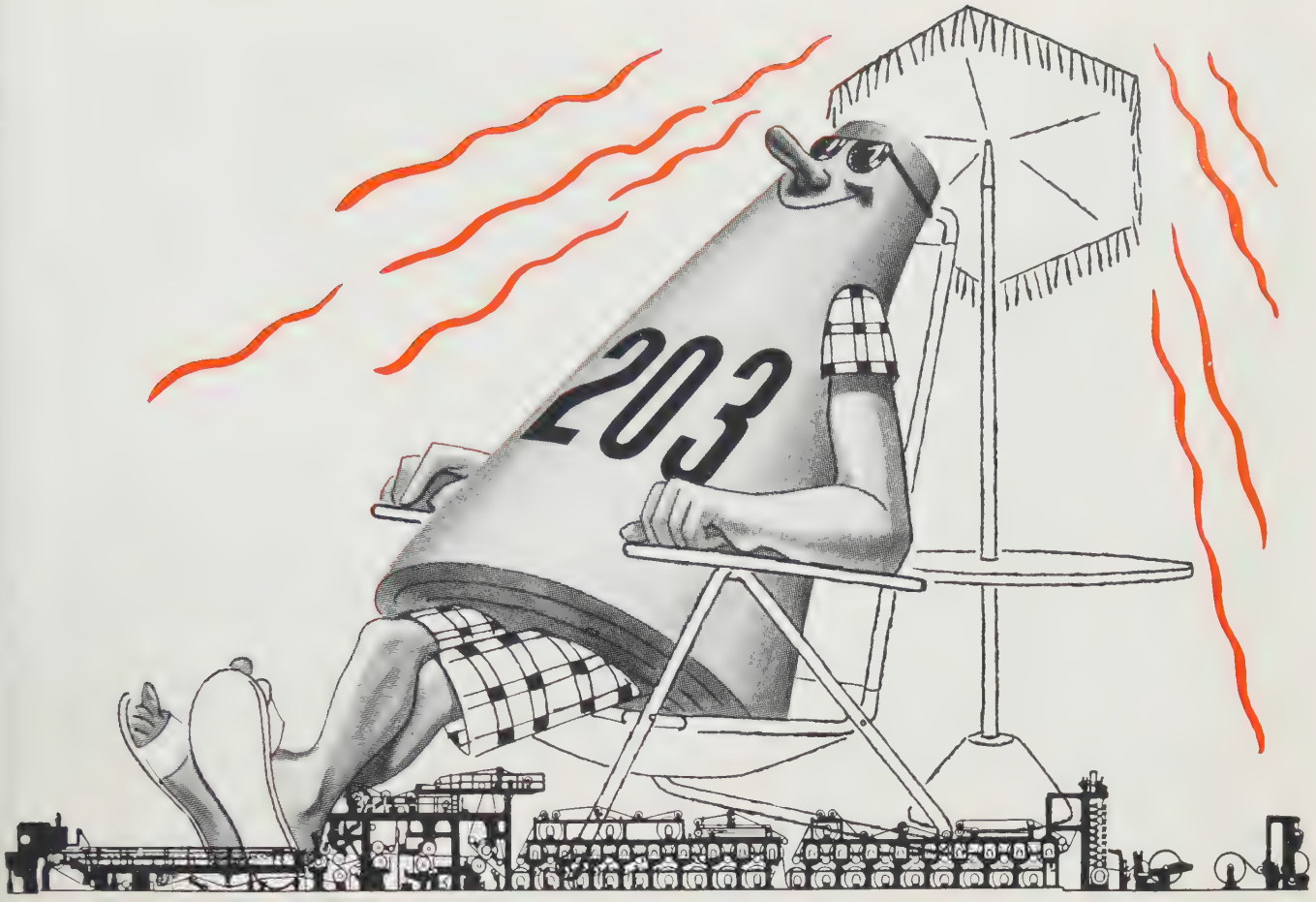
Subsidiaries in England, Italy, Mexico, Spain, Venezuela and West Germany
In Canada: Alchem Limited, Burlington, Ontario

Nalco® ... *Serving the Paper Industry through Practical Applied Science*

Nalco CHEMICALS

No matter what your product, process or problem involving white pigmentation, look to TITANOX® pigments and our technical service for the answer. Titanium Pigment Corporation, 111 Broadway, New York 6, N. Y.; offices and warehouses in principal cities. In Canada: Canadian Titanium Pigments Ltd., Montreal.

7541



DRESSED TO BEAT THE HEAT!

WOODBERRY 203

Full Faced Asbestos Dryer Felt

WOODBERRY 203 is a heavy, full-faced asbestos dryer felt . . . engineered to yield superior drying performance in rugged, hot positions. The heavy cotton body construction gives it great strength while the full asbestos face protects the felt from the deteriorating effects of unusually high temperatures and excessive chemical concentrations. WOODBERRY 203 is ideally suited to the rigorous demands of the board and kraft industry . . . but it will serve equally well, wherever tougher, heat-resistant clothing is required. It is as economical as it is effective! On a cost per ton basis, WOODBERRY 203 often far surpasses even more costly felts. Sold only pre-stretched and pre-shrunk (with or without clipper seams).

MOUNT VERNON DRYER FELT FAMILY– WOODBERRY 203 is just one of Mount Vernon's full "family" of scientifically engineered dryer felts. In this "family" you will find an individual felt for virtually every paper machine position and every paper-making need.

Another Mount Vernon Dryer Felt Success Story . . .

A #1 machine producing kraft liner and board specialties was being operated at higher-than-average speeds and temperatures. The operation proved costly and inefficient because the dryer felts being used were unable to withstand the grueling conditions on certain machine positions. After carefully studying the problem, Mount Vernon technicians recommended WOODBERRY 203, a dryer felt engineered to provide superior drying performance in the hottest positions. Result – WOODBERRY 203 ran for 121 days in marked contrast with the average 90 day life of ordinary felts . . . thus yielding a dryer felt cost per ton of only $.039!

UNIFORMITY Makes The Big Difference In Industrial Fabrics

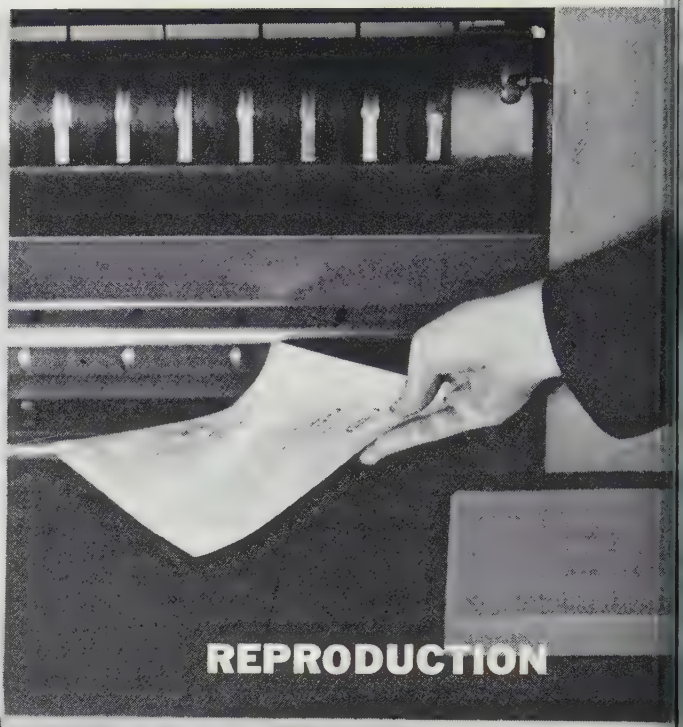
Mount Vernon Mills, inc.

A LEADER IN INDUSTRIAL TEXTILES

TURNER HALSEY COMPANY

SELLING AGENTS

Main Office: 40 Worth Street, New York, N. Y.

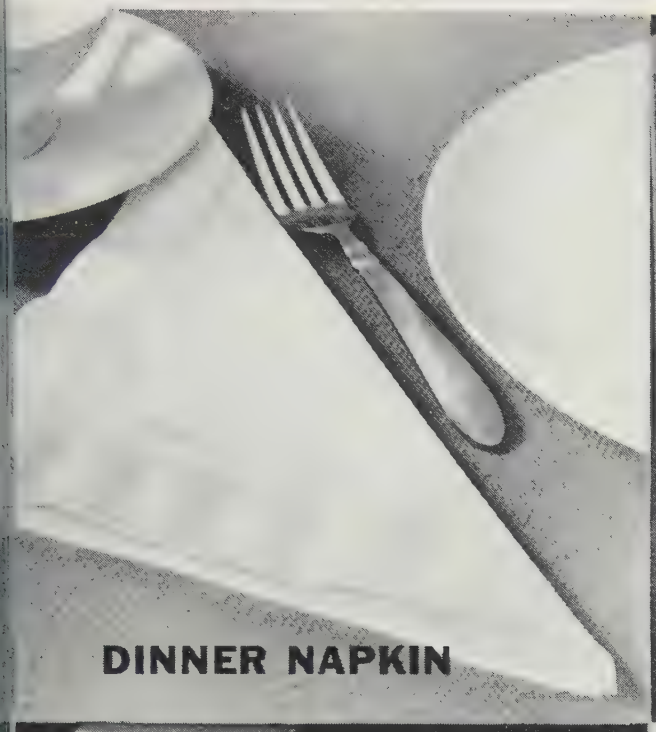


Eight papers . . . improved by a

Name your paper—and Alberta HI-BRITE Pulp will help you make it better! Now proved in more than one hundred North American paper mills, Hi-Brite is truly the modern pulp for modern, quality papers.

Why does Hi-Brite do so much more than ordinary pulps? *First,* it's produced exclusively from northern spruce and lodgepole pine. *Second,* Hi-Brite pulp is "cold-blown" from Kamyr continuous digesters to preserve the bonding strength of the long, thin fibers. *Third,* Hi-Brite's ultra-modern bleaching process actually improves the inherent strength of the unbleached fibers.

Hi-Brite . . . and Hi-Brite alone . . . has this



single pulp–Alberta Hi-Brite®!

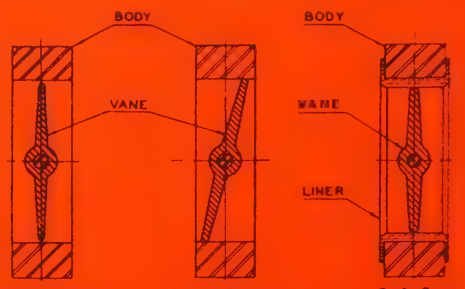
unique combination! The result–a uniform pulp of gleaming whiteness with outstanding bonding properties!

Get the full story on Alberta Hi-Brite Bleached Sulphate Pulp... and the advantages it offers your paper-making operation. St. Regis Paper Company, 150 East 42nd Street, New York 17, N. Y.

KRAFT DIVISION

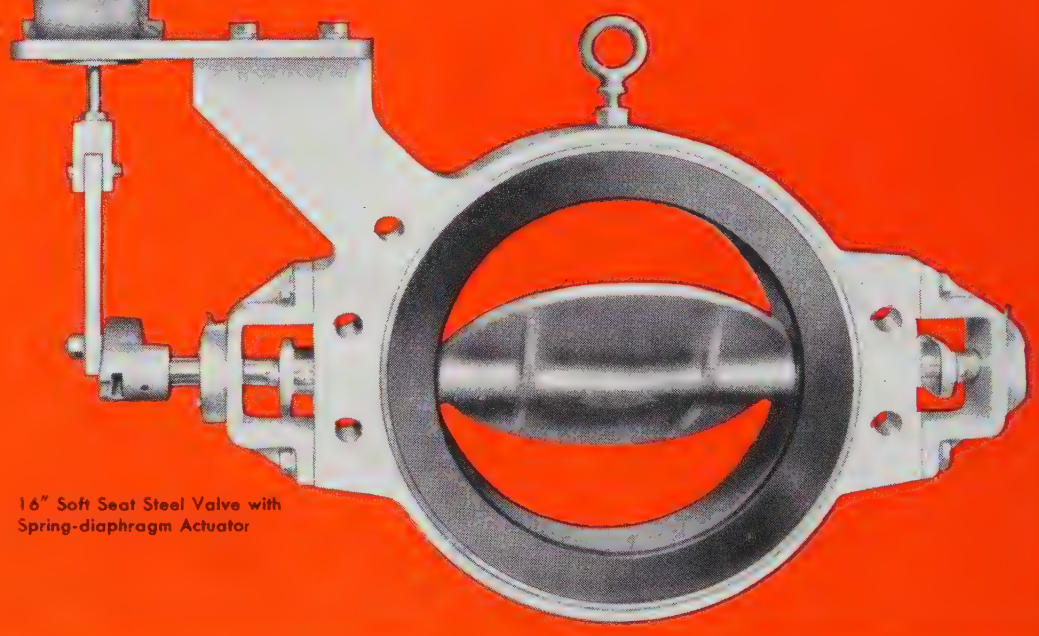
St.Regis PAPER COMPANY

from Mason-Neilan...



Swing-through Angle Seating Soft Seat

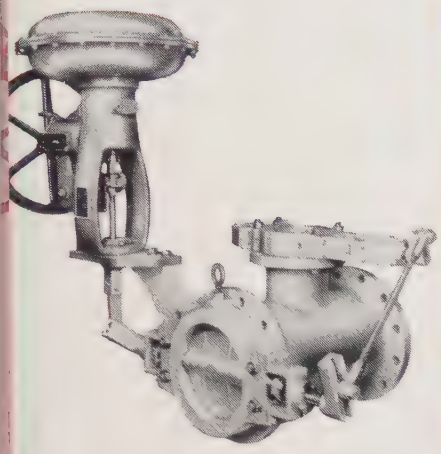
Choice of nonseating or seating types



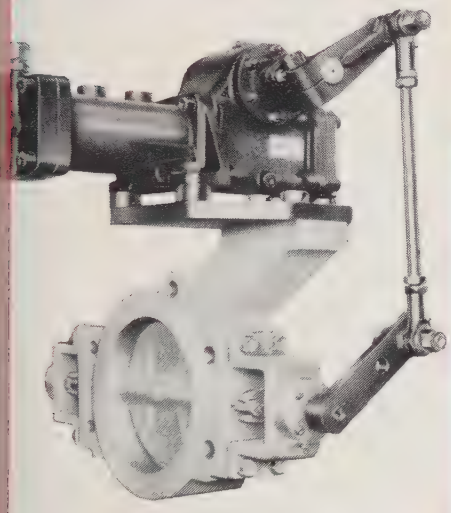
16" Soft Seat Steel Valve with
Spring-diaphragm Actuator

Flexibility in Butterfly Valve Application

With Wide Selection of Actuators, Choice of Swing-through or Seating Types

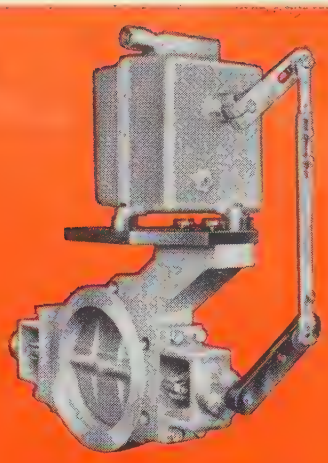


10″ x 10″ x 6″ Heavy Duty Tee Valve with Spring-diaphragm Actuator and Side-mounted Auxiliary Handwheel

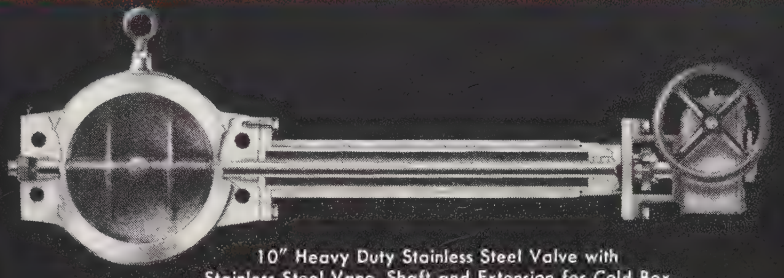


8″ Heavy Duty Steel Valve with G.P.E. Crank Type Cylinder Actuator

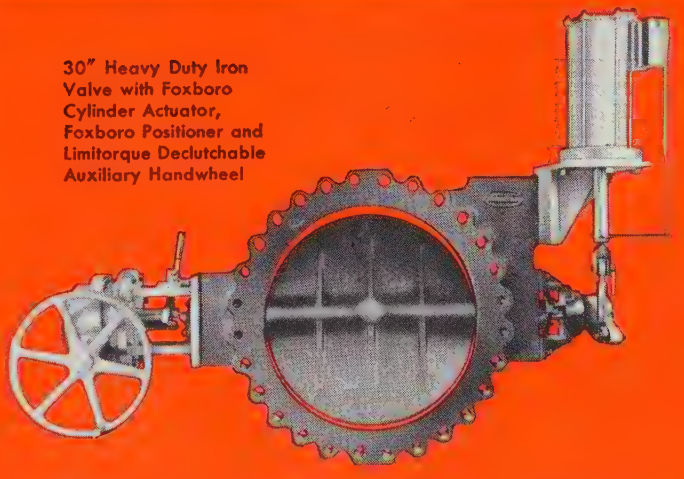
8″ Light Duty Steel Body Assembly with Kel-F Coated Body and Vane



8″ Heavy Duty Steel Valve with Barber-Colman Electric Actuator



10″ Heavy Duty Stainless Steel Valve with Stainless Steel Vane, Shaft and Extension for Cold Box Installation in Oxygen Service



30″ Heavy Duty Iron Valve with Foxboro Cylinder Actuator, Foxboro Positioner and Limitorque Declutchable Auxiliary Handwheel

Mason-Neilan offers a broad line of butterfly valves with a choice of nonseating, angle seating, or soft seat wafer bodies and a wide variety of power and manual actuators.

The few typical examples shown here are indicative of the scope of the Masoneilan line. These, and the many other variations available, exemplify the quality and design features resulting from over 75 years of experience in valve manufacturing.

For control of large volumes of liquids or gases, select Masoneilan Butterfly Valves. Complete information on request, ask a Mason-Neilan representative or write to:

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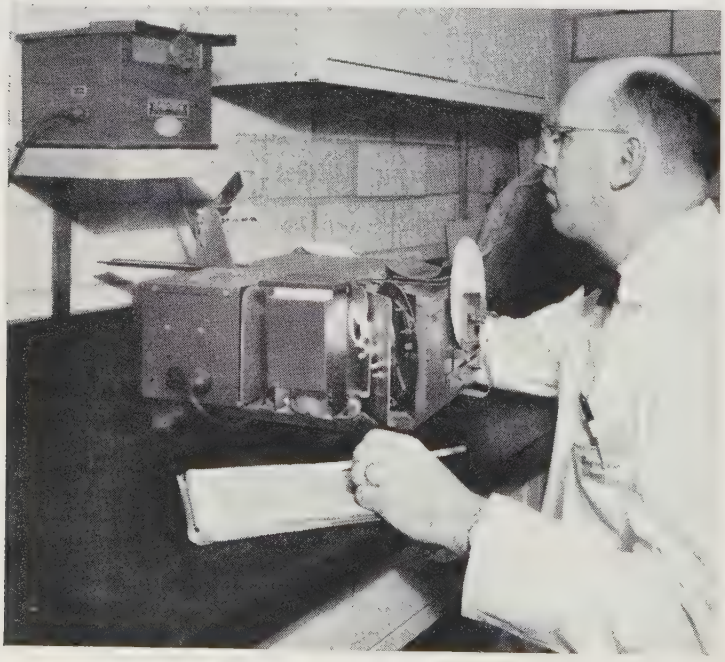
MASONEILAN

MN9-38

U.S.I. SERVICES THE PAPER INDUSTRY WITH TECHNICAL LAB ASSISTANCE...

IN PACKAGING – From studies such as this test of heat seal strength, U.S.I.'s Polymer Service Laboratory develops recommended procedures for all aspects of polyethylene packaging.



IN PULPING – Tech Service Engineer at U.S.I.'s laboratory-scale pulp and paper "plant" determines brightness of a hand sheet he has made from customer's pulp, on Hunter Multipurpose Reflectometer. He will also test it for tensile and bursting strengths, folding resistance.

in pulping
in converting
in packaging

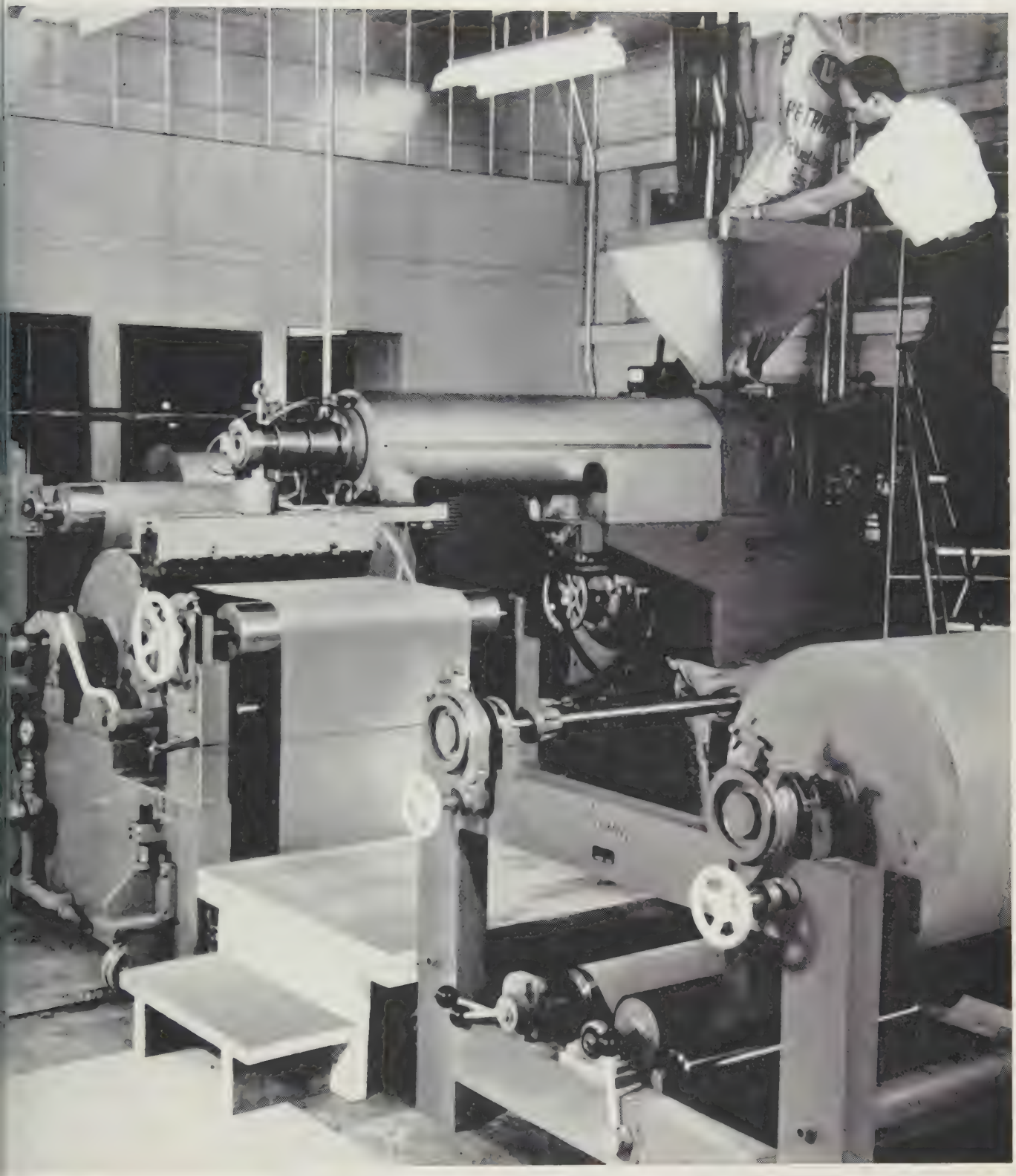
Whether you're pulping, converting or packaging paper products, U.S.I. has a laboratory and staff devoted to technical service in your field. Its job: to see that U.S.I. products for the paper industry give you the results you need in your operation.

U.S.I.'s pulp and paper laboratory — built eight years ago when U.S.I.'s Huntsville, Alabama, chlorine and caustic soda plant began operation — is a miniature paper plant, complete with auxiliary testing equipment. Here our engineers work on bleaching and assist with other applications of U.S.I.'s chlorine, caustic, ammonia, sodium peroxide . . . determine systems, techniques, types and concentrations of chemicals so that customers will know how to produce the brightest pulp with minimum fiber degradation.

Another lab at Tuscola, Illinois, is staffed with experts on polyethylene technology—including coating of paper and board, and packaging of paper products for the consumer market. They have equipment to duplicate commercial production and testing techniques . . . to tackle any problem involving an application for PETROTHENE® polyethylene resins.

A vital part of the Polymer Service Laboratory's work is development of new polyethylene paper coating and paper products packaging techniques along with design of necessary equipment.

Write or call for more information on how these services can work for you in improving your products . . . expanding your markets.



IN CONVERTING — Duplicating commercial equipment in everything but width, this coating machine at U.S.I.'s Polymer Service Laboratory is a key factor in developing new polyethylene resins for specific substrates. Latest products to come out of such work are three new PETROTHENE® resins designed for paper coating applications.

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*Idea submitted by Hugh W. Gorton, Missisquoi Specialty Board Div.—Std. Packaging Corp., Sheldon Springs, Vermont

Photo by Ewing Galloway, N. Y.

"Reminds me of HAMILTON Felts . . . you can look far and wide and still not beat 'em"

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is surely well named,"
says Hugh W. Gorton.
"From it, on a clear day,
you can see seven states!

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you can look far and wide, too,
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you can't beat Hamilton Felts!"

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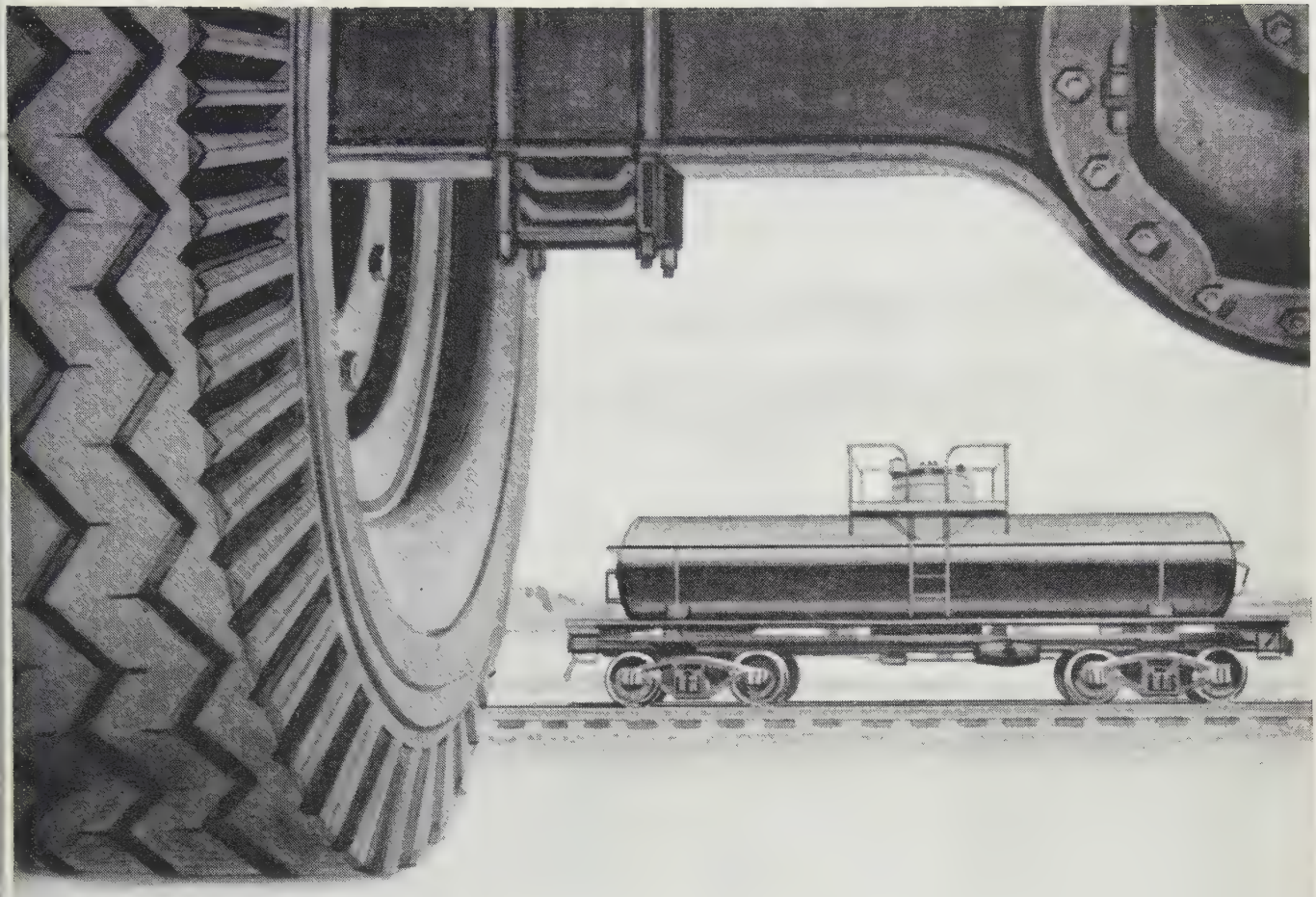
SHULER & BENNINGHOFEN, HAMILTON, OHIO



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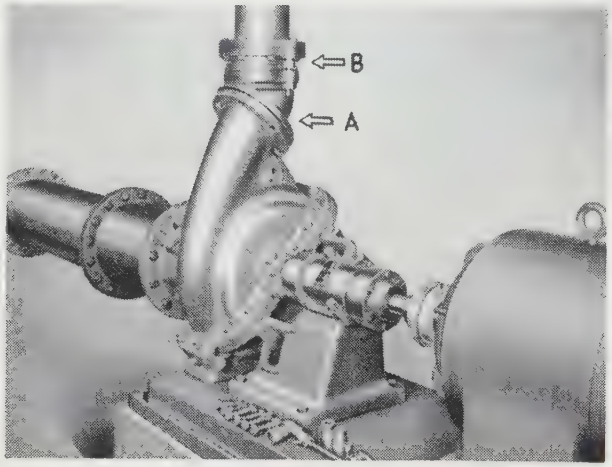
You can go right into this Goulds stock pump in less than ten minutes should you want to check or take out its rotating element.

Diagonally split, hinged-cover casing with jacking bolts lets you open the casing quickly and easily.

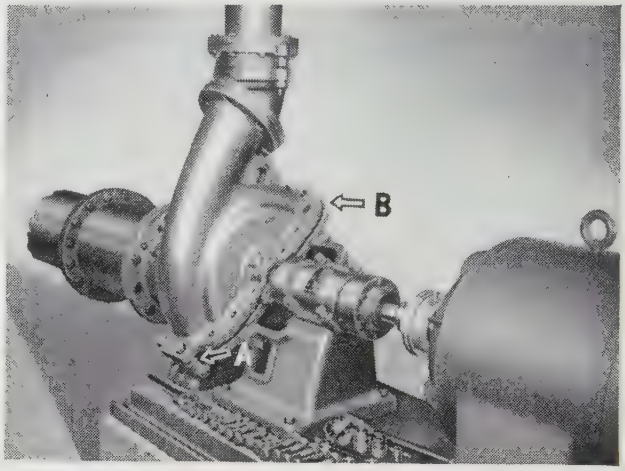
You can then remove the entire rotating element, including bearing assembly, without disturbing pipe connections.

Goulds Pumps Inc., Dept. TA-50, Seneca Falls, N. Y.

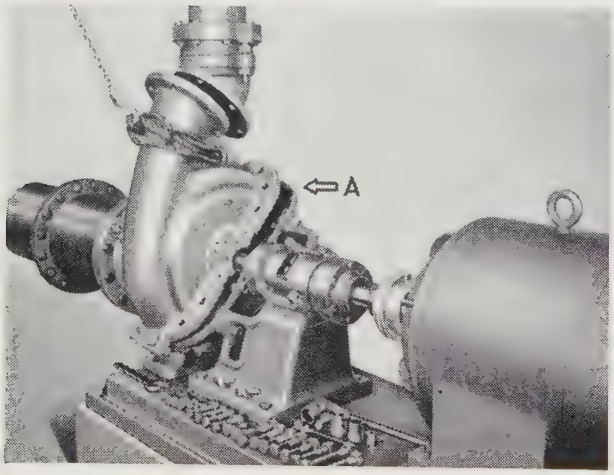
HERE'S ALL YOU DO:



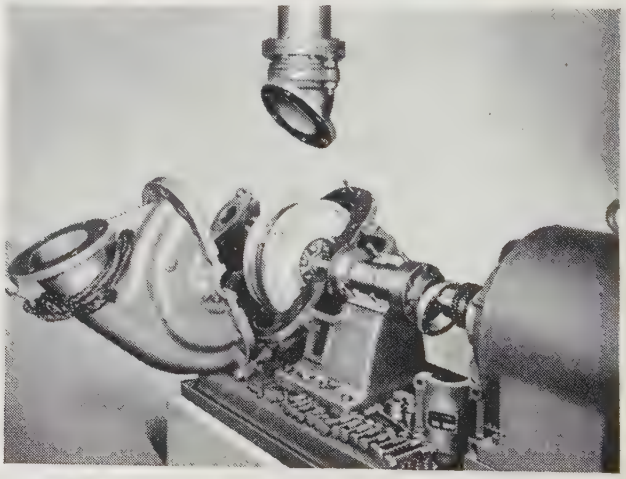
1. Take out bolts connecting the discharge elbow and upper half pump casing (A). Loosen upper nuts on jacking arrangement (B), tighten lower nuts, telescope discharge elbow into discharge connection. Time: 5 minutes.



2. Remove parting bolts connecting two halves of pump casing. Loosen top nuts on hinge pins and tighten hex nuts (A) to raise casing. Complete flange break by means of jacking screw (B). Time: 15 minutes.

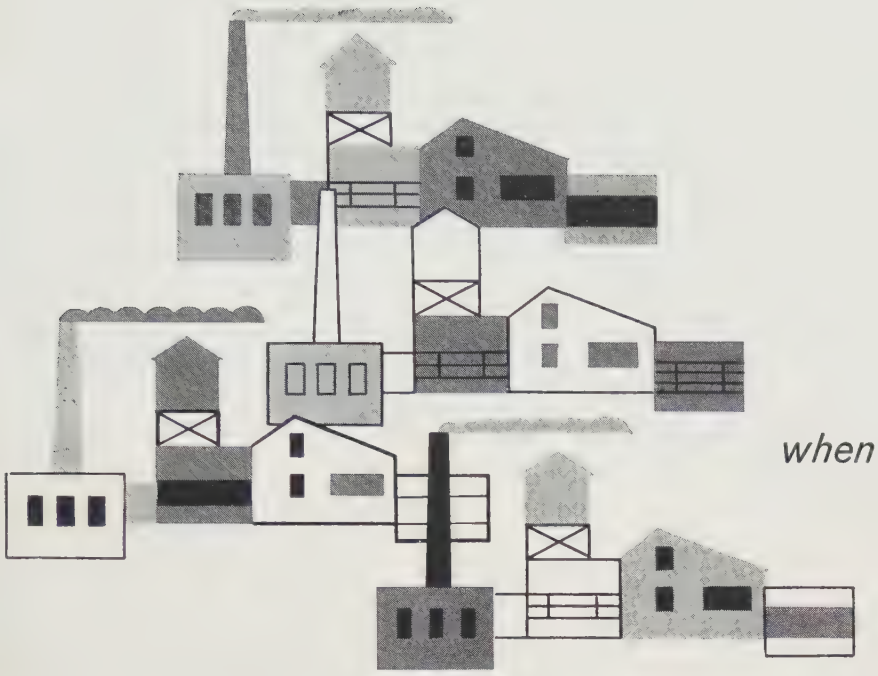


3. Attach chain fall through upper half pump casing. Using jack screws (A), continue raising casing. Time: 2 minutes.



4. Model 3135 pump is now completely open. Remove bearing cap, disconnect coupling. Rotating element now comes out easily. Time: 5 minutes.

GOULDS PUMPS



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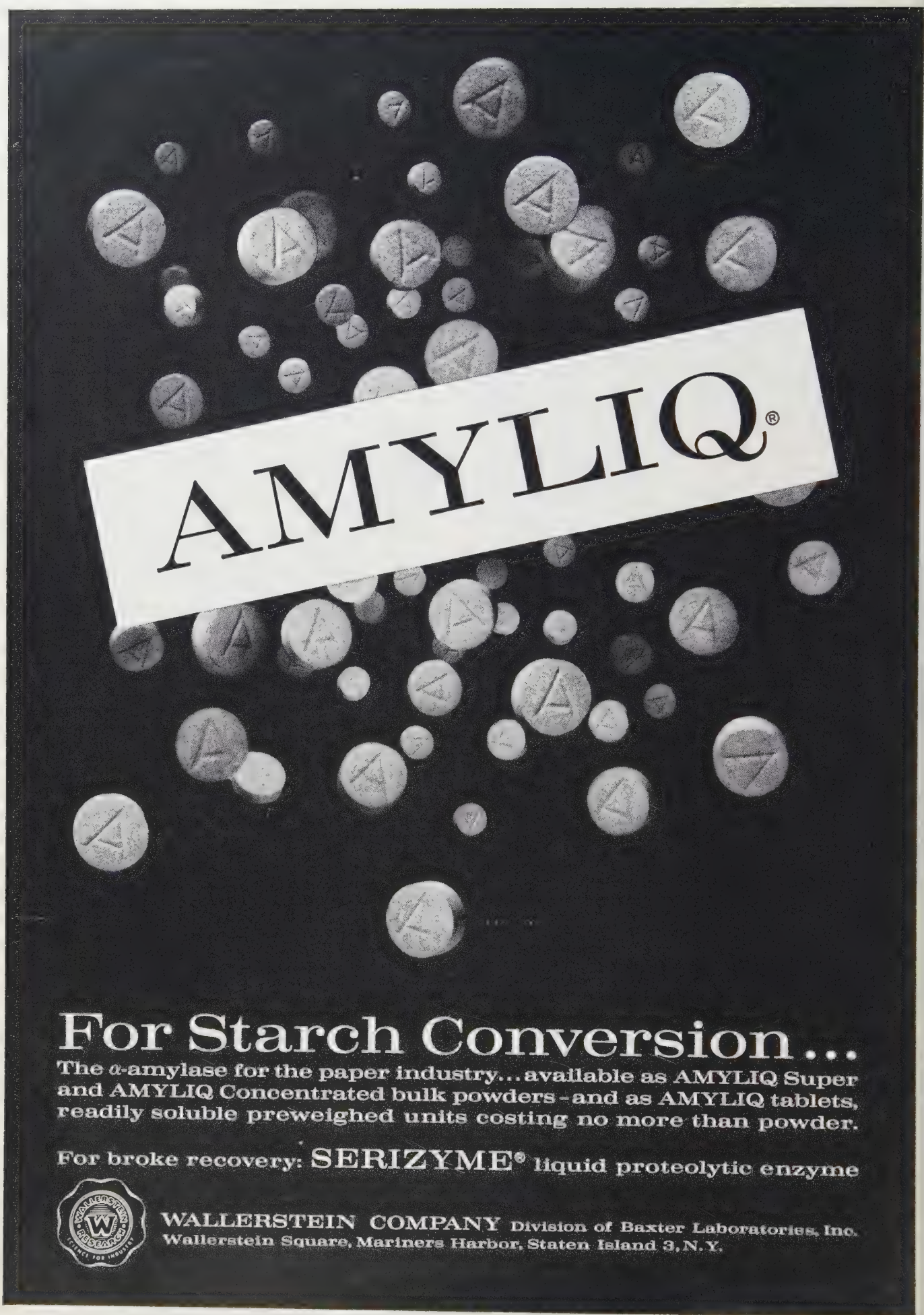
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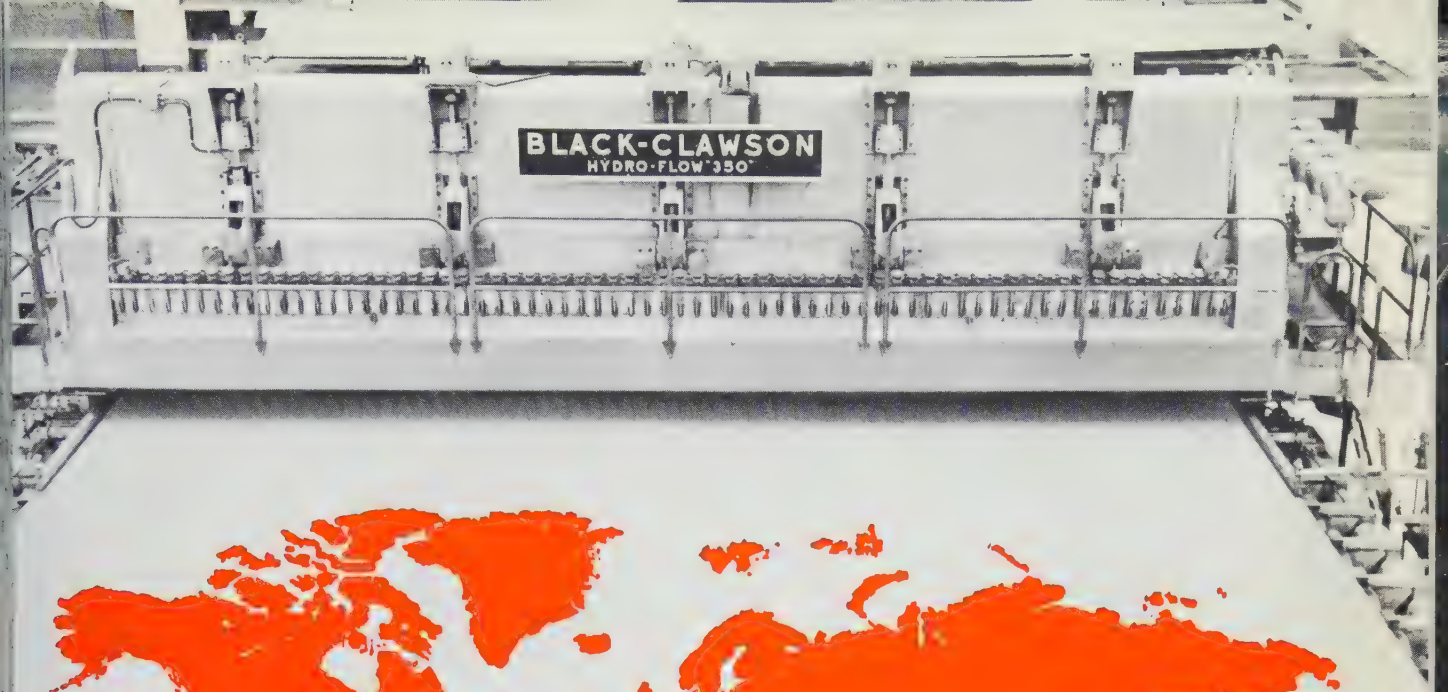

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NEWSPRINT MACHINE

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The scope of Black-Clawson service to the world-wide pulp and paper industry continues to multiply in two ways.

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. . . in the creation of new machinery and technical developments for every phase of pulp and paper production from pulp mill to converting plant.

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Paper Coating
Detergency
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SYNTHRAPOL RWP
A low foaming surfactant which confers excellent rewetting properties. Also, ideal for cleaning felts when low foaming is desired.

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contributes to improved printability and luster; reduces dusting.

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facilitates applications of paper coating and improves quality of the finish.

For Deresination
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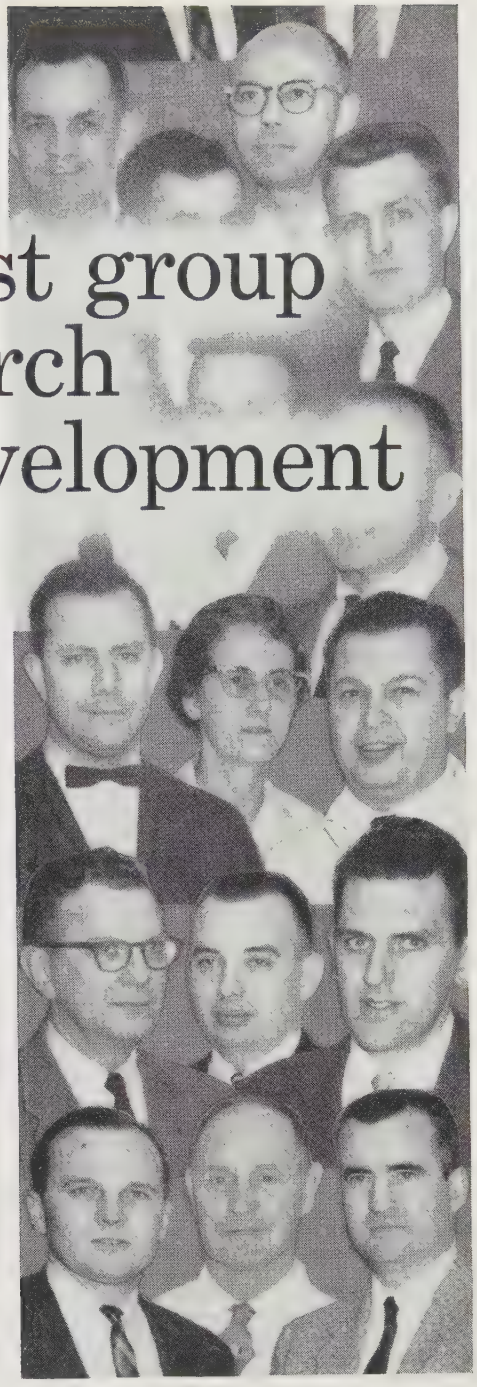

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FROM DU PONT RESEARCH . . .

The first Titanium Dioxide Pigment

COMPARISON OF RETENTION PROPERTIES between "Ti-Pure" HR and conventional TiO_2 is demonstrated by Dr. Harold C. Brill, Paper Section Manager, at the Du Pont Pigments Department, Technical Service Laboratory. Mixtures of chlorinated starch and pigment were prepared and then poured through filter paper. Note particles of the conventional pigment have run through the filter paper in left test tube, while the HR filtrate in the right test tube remains clear. HR has not passed through the paper. Your Pigments Representative will perform this desk-top experiment for you in your plant, if you wish.

xpressly designed for wet-end addition

TI-PURE® HR

offers high one-pass retention...cuts pigment costs up to 15% in the presence of starch

Now you can cut the amount of titanium dioxide pigment added in the wet-end and still give uniform high brightness and opacity to bond, offset and other quality printing papers. The reason is new Du Pont "Ti-Pure" HR—the first titanium dioxide pigment developed expressly for papermaking.

"Ti-Pure" HR offers better one-pass retention in the presence of oxidized starches than any other pigment. (The HR stands for High Retention.) In systems without starch, HR has retention equal and sometimes superior to commonly used beater-grade pigments.

Plant run shows difference in retention

In a typical plant run, the titanium dioxide content of finished sheets showed these differences: conventional titanium dioxide plus a retention aid, 5.0%; "Ti-Pure" HR, under optimum conditions, 6.4%.

This superior retention naturally means less pigment loss to the sewer, less load on save alls. Several mills that have recently switched to "Ti-Pure" HR report savings up to 15% in pigment costs.

HR has unique properties

"Ti-Pure" HR is a water-dispersible pigment that can be added dry, or used in mills with wet slurry systems. It has outstanding suspension properties, minimizing the problem of settling in the float chambers of the metering pump. HR is not flocculated until alum or other flocculating agents are added and offers opacity and brightness, dry or waxed, similar to commonly used beater grades of anatase TiO_2.

RESULT: BETTER CONTROL over the pigment content of your papers, more uniform paper quality. Let your Du Pont Pigments Representative tell you about "Ti-Pure" HR. He'll run a demonstration for you that dramatically compares the retention qualities of HR with a standard pigment (see picture left).

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Pigments Department, Wilmington 98, Delaware

TI-PURE® HR
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...THROUGH CHEMISTRY

Part of the Permutit Precipitator-filter-demineralizer plant treating 2 million gallons of water per day at West Virginia Pulp & Paper Company, Charleston, S. C.

She's only five foot two, but she "operates" these six Permutit Valveless Filters

• If these were standard manually-operated gravity filters, it would take 3 husky well-trained men (3 one-man shifts) to open and close heavy valves for shutoff, backwash and rinse. If they were table-controlled automatic filters, the initial cost would be almost *doubled.*

Fact is these filters are in the same price range as manual filters, yet they are *completely automatic.* They shut themselves off from service at just the right bed condition. They backwash and rinse at the most efficient flow rates and for a pre-set length of time. Then they put themselves back into service. The little lady doesn't have to touch them!

Permutit Valveless Filters use a simple design employing basic hydraulic principles to do the "thinking" and the work . . . replacing expensive valves, flow controllers and hydraulic or pneumatic control systems. Initial installations have been approved for treatment of drinking water as well as process water.

Our new Bulletin No. 4351 tells how you can cut both initial and operating costs with Valveless Filters. Call the nearest Permutit man or write to The Permutit Company, Dept. TA-50, 50 West 44th Street, New York 36, N. Y., or Permutit Company of Canada, Ltd., Queens Quay, Toronto 1, Ontario.

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Whether turkey tracks, hen tracks, orange peel—whatever term you use to describe these imperfections, remember this: Ethylex Gums produce superior surface sizings almost free of patterning. Exceptionally strong film-forming characteristics and self-leveling flow properties assure uniform distribution of size. Ethylex Gums control penetration, improve gloss ink hold-out.

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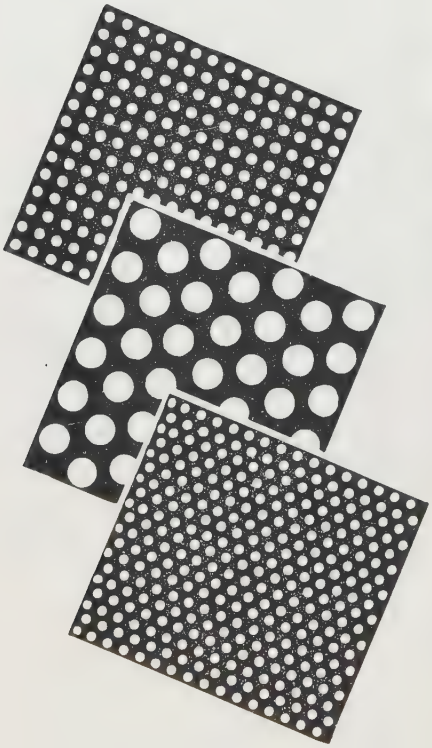
THE RESULT OF 57 YEARS EXPERIENCE

Burr Free PERFORATED SCREEN PLATES



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STAINLESS STEEL* MONEL INCONEL
COPPER ALUMINUM BRONZE STEEL

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Consult "UNION" for your needs — we will be pleased to quote on your requirements.

*Stainless Steel Plates can be Electropolished (patented process) at a slight premium. This process has been found to improve screening characteristics in many cases.

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"We offer free mill trials to show the fine results and low cost of groundwood pulp one-stage hydro bleaching—the only cost to the mill is for the hydro"

George V. Rittenhouse (left) and Robert W. Barton

Technical representative Bob Barton and salesman George Rittenhouse, both of Virginia Smelting Company, answer some questions regarding the efficiency of bleaching groundwood pulp with one stage of hydro.

Q Do zinc and sodium hydrosulfites provide the most economical method of one-stage pulp bleaching?

Mr. Barton—If the mill is going for anything between 2 and 11 brightness points, bleaching groundwood pulp with hydro is virtually always the cheapest method. It is easier to apply—there are no control tests involved—and the chemical cost is much lower.

Q Is it difficult to set up a trial run for a mill that might want it?

Mr. Barton—Not usually. Frequently much of the equipment we need is available in the mill. We go in with our lab equipment and make tests, checking the *p*H we're going to deal with, and possibly deciding on the maximum temperature possible. We give all the facts to the mill—and if they want the trial, we set it up. Often the mill has a pulp storage chest. A few changes and we can use it as a bleaching tank. We'll bring in feeders, attach hoses, and start the trial.

Mr. Rittenhouse—Our technical men stay there until the setup is running perfectly and they make sure the operators know everything they need to. You'd be surprised at what we run into sometimes, even in mills that have been bleaching regularly with hydro. They take the powdered hydro and dump it in on top of the stock. Of course, hydro breaks down fast when it is exposed to air, and they wind up with reaction times too short—temperature not showing the proper effect—and poor brightness response at the end. I might add that faulty mixing like this can cause a corrosion problem, too—a problem that does not arise if proper air-free mixing is standard procedure.

Mr. Barton—A good point, George. This is the chief reason why some mills are under the mistaken impression that hydro always causes a corrosion problem. If hydro is handled properly there's no corrosion problem.

Q Isn't a mill trial a pretty extensive service at no charge?

Mr. Rittenhouse—Yes, I suppose so—but I consider it the most effective way of showing a mill the economy and the good results obtainable with hydro. After all, mill trial data offer the most believable evidence of what I say. And production doesn't have to be stopped—we can almost always set up the mill trial without affecting it.

Q What are the advantages to the mill in using a "Virginia" hydro?

Mr. Barton—There are several. One is the consistently uniform quality and purity of our hydro, either the zinc or sodium. It's a very clean, free-flowing powder—made, packed and shipped as moisture-free as modern manufacturing methods can make it.

Mr. Rittenhouse—And of course our technical service goes with it. A mill can always call for assistance and get a "Virginia" technical man. It's the accepted thing with our customers.

• • •

FOR A FREE MILL TRIAL

—just drop us a line, phone or wire, and a representative will call on you at your convenience.

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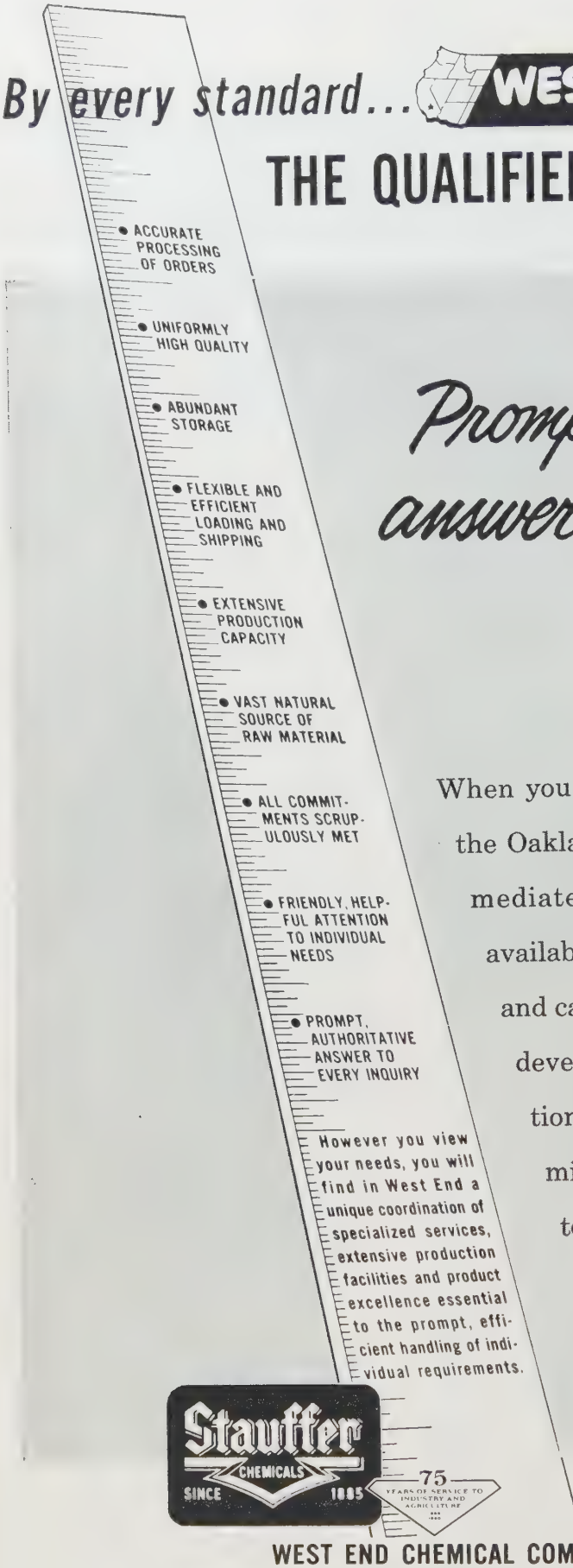
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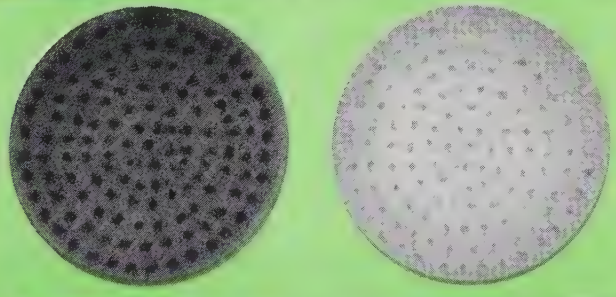

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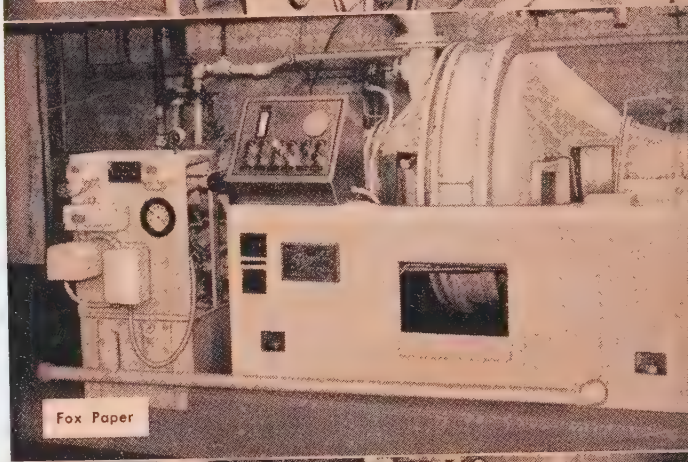

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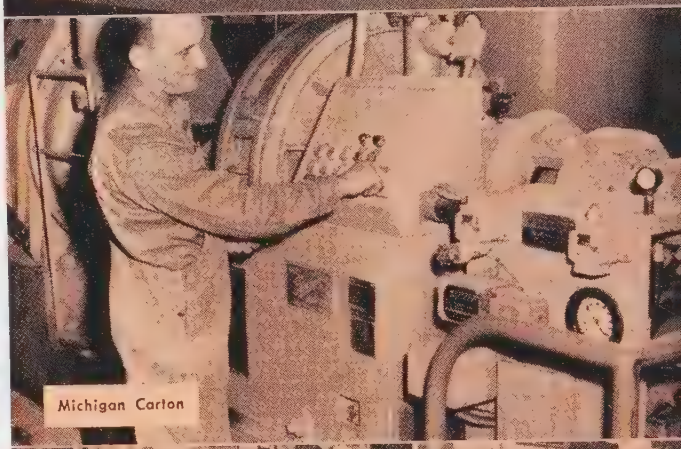

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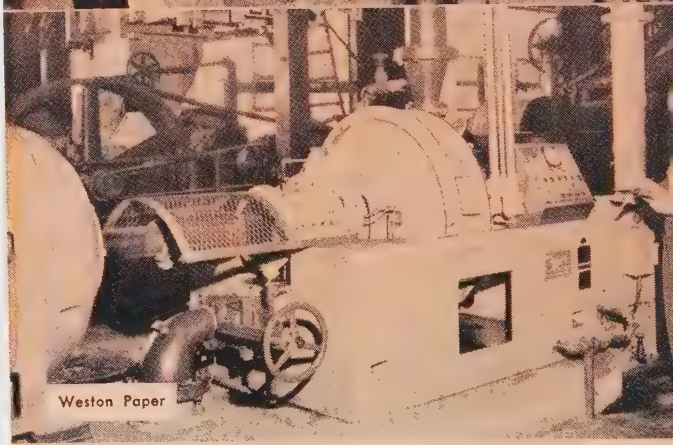

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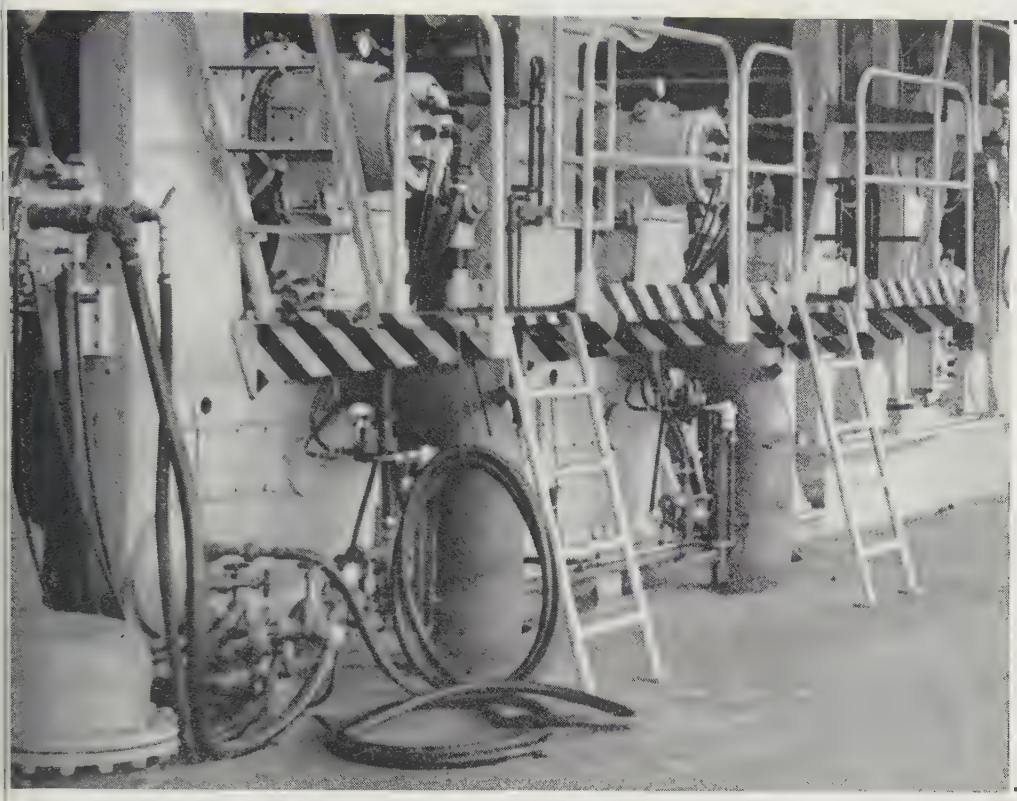

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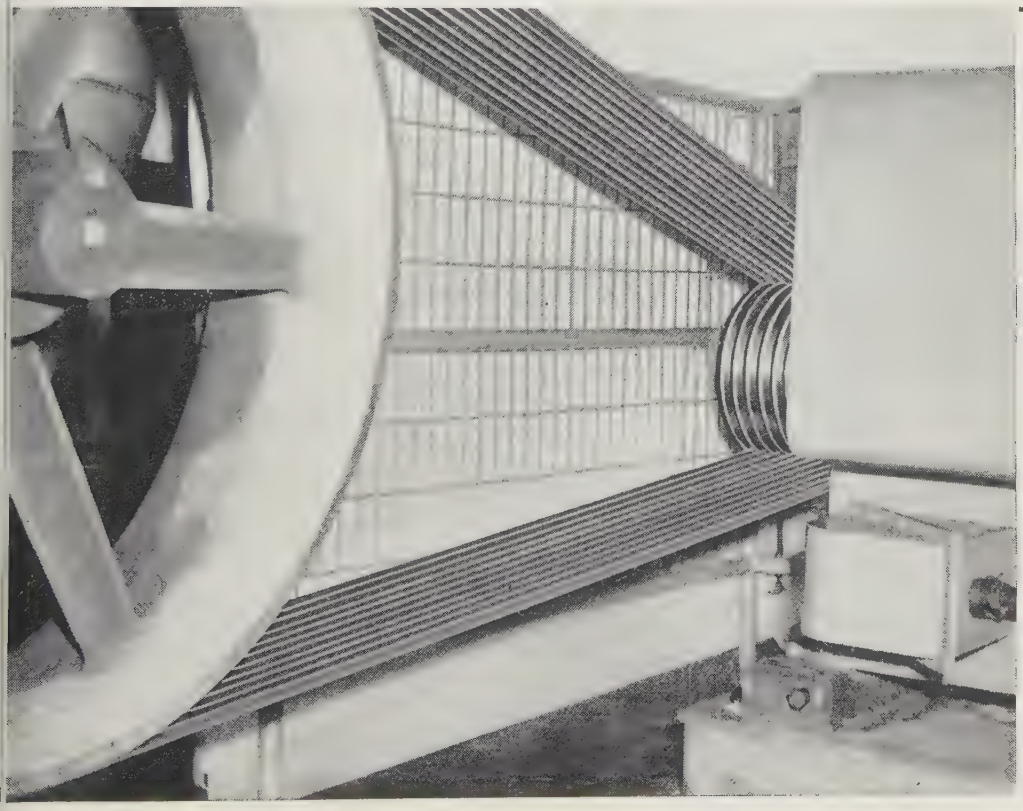

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PP60-1

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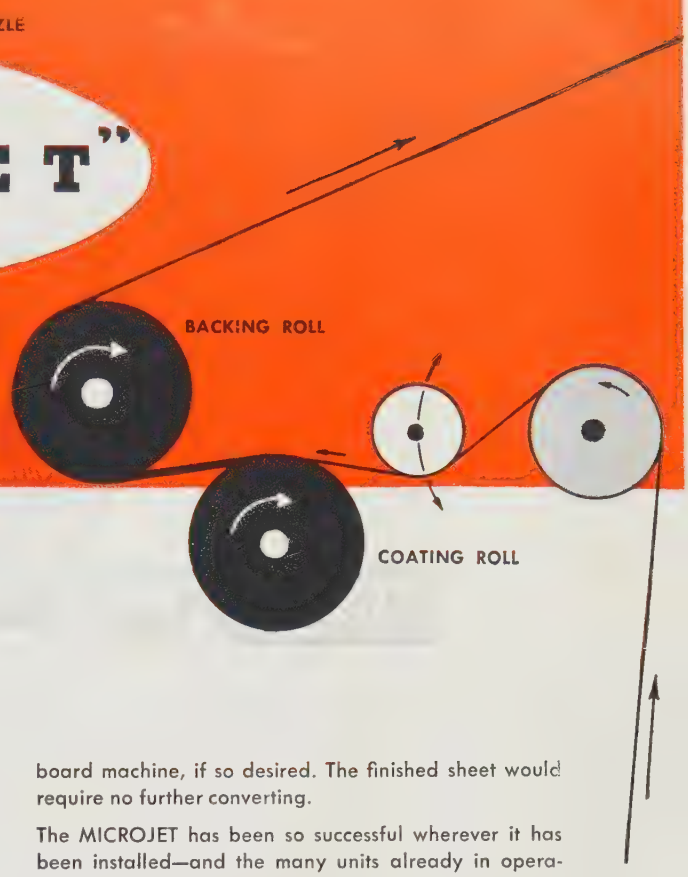

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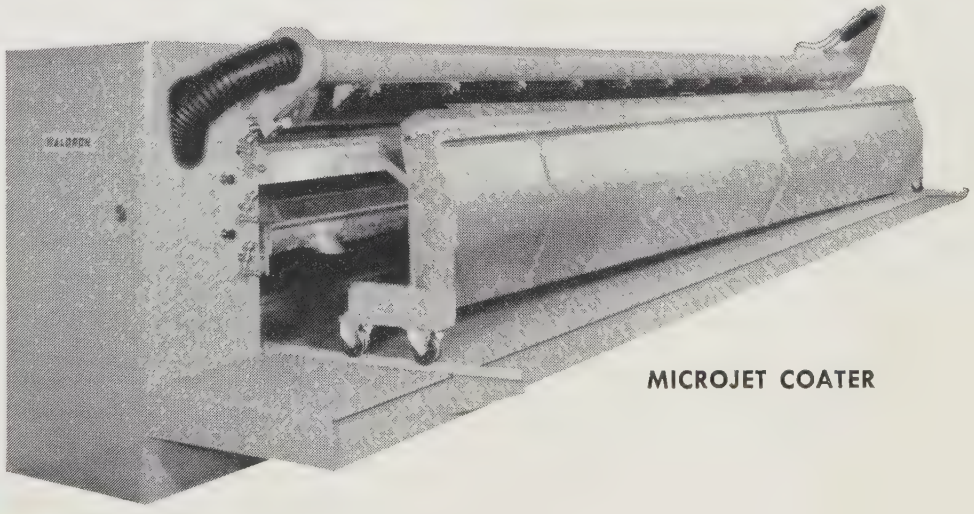
Gulf States Paper Co.	1
Potlatch Forests	2
Alton Box Board	1
United Board & Carton	1
Union Bag-Camp Paper Corp.	1



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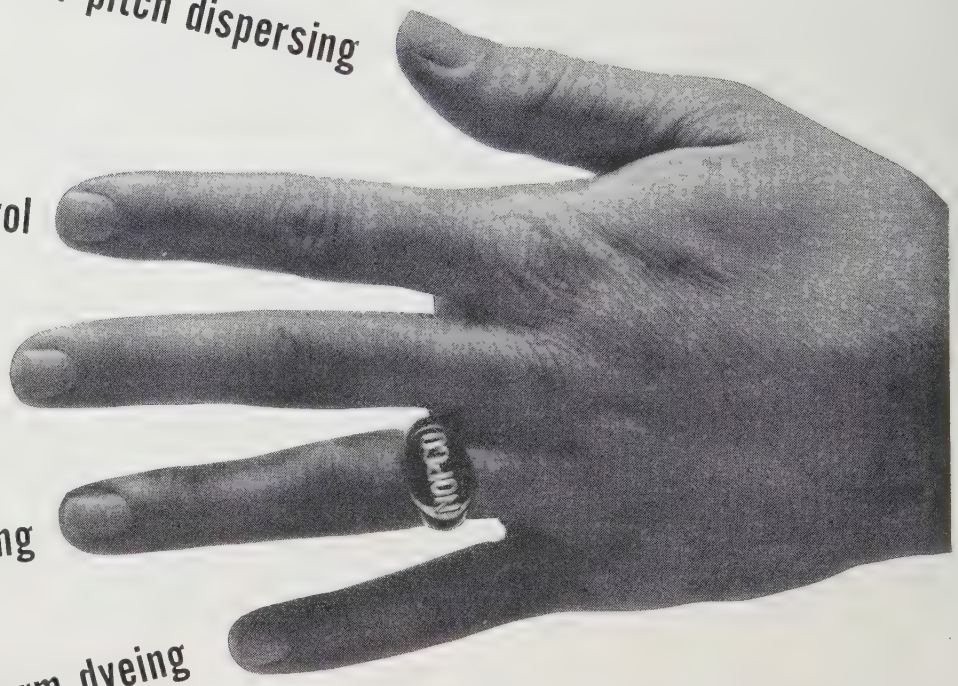

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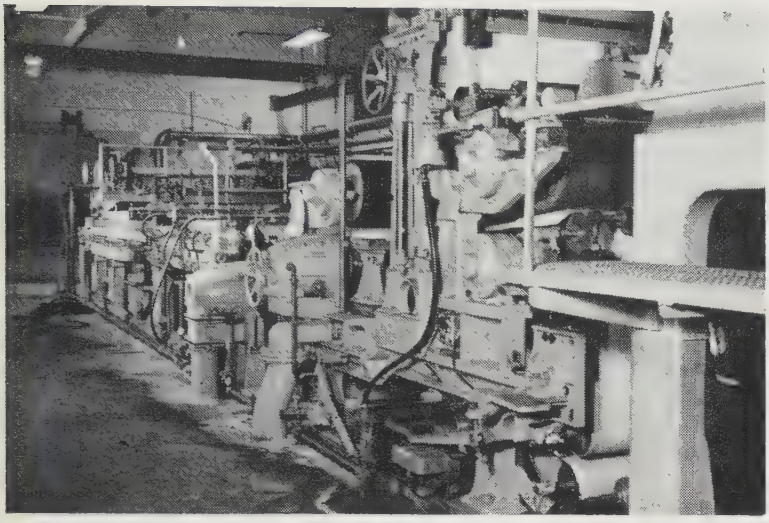

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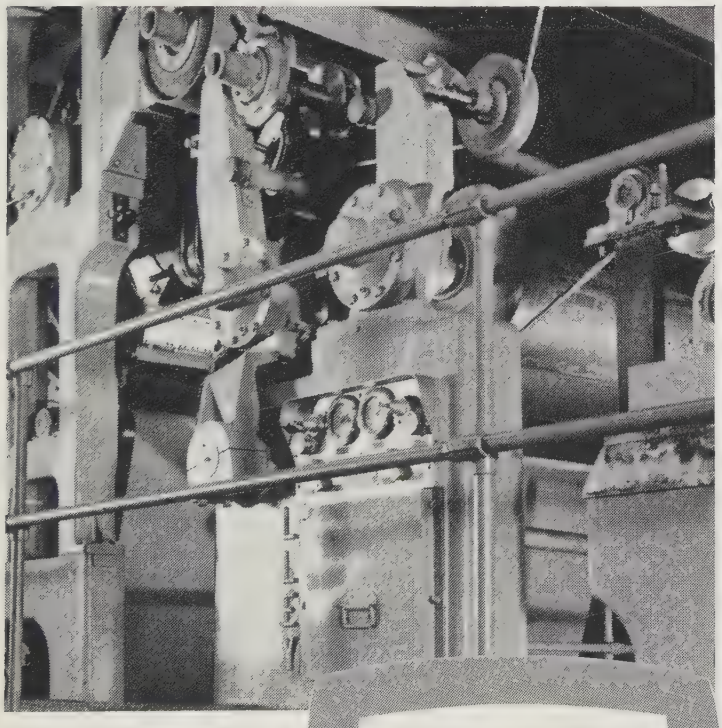

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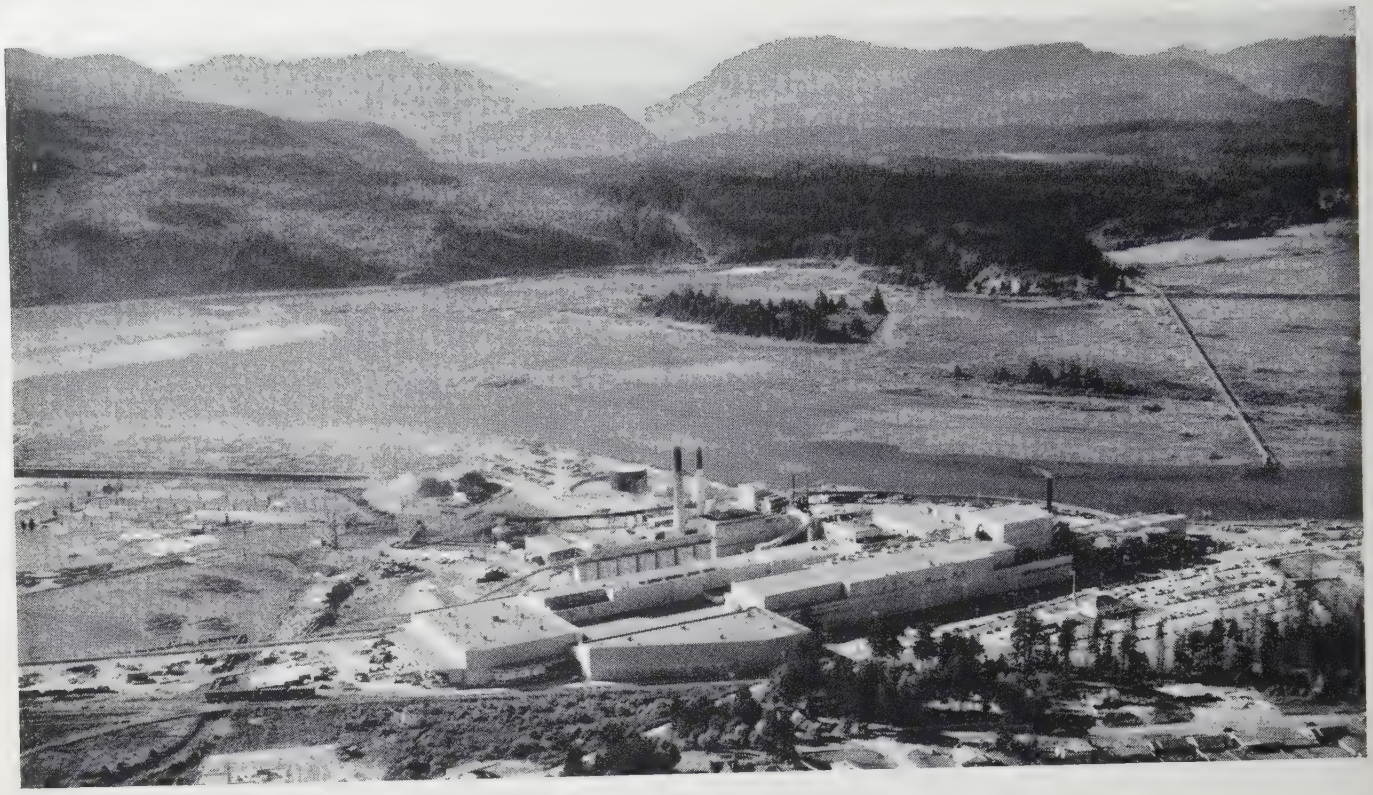

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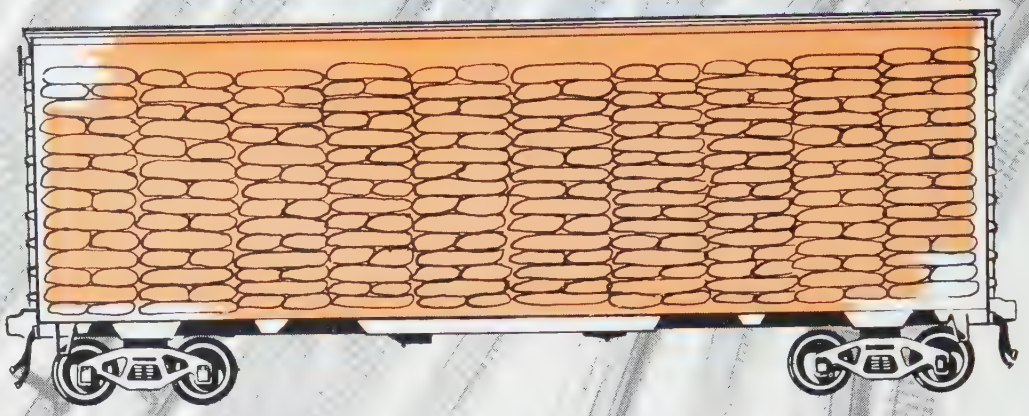

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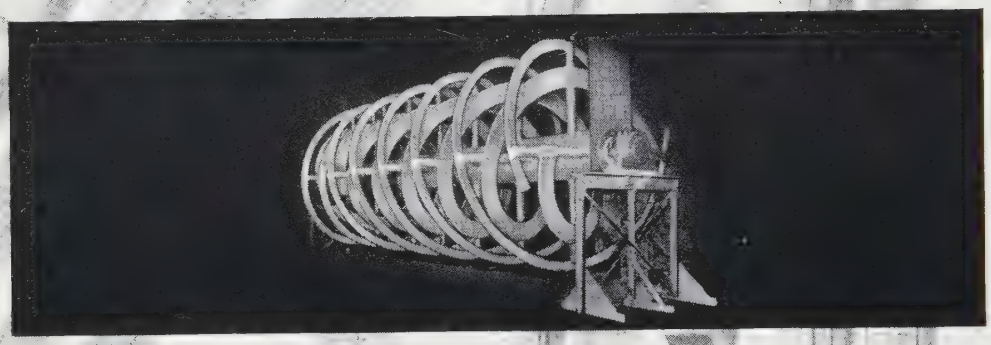

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Measurement of the Smoothness of Paper

T. W. LASHOF and JOHN MANDEL

The details of an interlaboratory study of the Bekk, Sheffield, and Bendtsen air-leak methods for the measurement of the smoothness of paper are presented. The data are analyzed using a procedure based on a linear model of the measuring process, and the results are interpreted in terms of this statistical model and the sensitivity concept. A comparison with previous work is also included. For the special series of mimeobond papers used in the study, good relationships were found between methods. Between-laboratory variability is appreciable in all three methods, but could be reduced with the aid of one or two standard samples. Both the Bendtsen and Sheffield methods suffer from scale-type errors due to the difficulty of bringing the several manostats of the Bendtsen or the several columns of the Sheffield into agreement with each other. When advantage is taken of their faster testing times to increase the number of specimens tested, the Bendtsen and Sheffield methods are slightly more sensitive to smoothness differences than the Bekk method.

THIS paper describes in detail an interlaboratory study carried out for the purpose of comparing three methods for the measurement of the smoothness of paper. The work reported herein was sponsored by a TAPPI task committee* formed jointly by the Graphic Arts Committee and the Paper Testing Committee for the study of airleak methods of measuring smoothness. The objectives of the study were: (1) to establish the relationship, if any, between the results obtained by the Bekk, Sheffield, and Bendtsen methods; (2) to determine the relative sensitivities of the methods; and (3) to determine instrument, observer, and laboratory contributions to the variability of the results so that realistic statements of precision may be included in the TAPPI Standard, when written.

Following a preliminary round robin which dealt primarily with obtaining estimates of precision at the various levels of smoothness, a more elaborate, main interlaboratory study was initiated, based on the linear model described in another paper (*19*). The results obtained in this study are interpreted in terms of this statistical model, the sensitivity concept (*17, 20*), and previous work by ourselves and others.

LITERATURE ON METHODS FOR MEASURING SMOOTHNESS

In an earlier paper (*17*) we presented a short survey of methods for measuring smoothness, including numerous references to the literature. Research on smoothness measurement continues with apparently increased intensity, giving witness to the importance of this property of paper. Recent basic studies relating the measured surface smoothness of paper or paperboards to printability have been reported by several investigators. Fetsko (*10*) reported that using the ink-transfer parameter at low ink-film thicknesses for comparison, none of the smoothness tests studied ranked all of the stocks in the proper order. She included the following methods: Bekk, Gurley, Sheffield, Bendtsen, Brush surface analyzer, Chapman, Scheid, Hull drawdowns, and surface photomicrographs. Hyvärinen, *et al.* (*16*) obtained a relationship between minimum compressibility and smoothness required for satisfactory photogravure printing. Prince (*22*) used multiple regression analysis to show that the total variance in the printability of newsprint is determined by smoothness more than by any other physical property. Luey (*18*), studying printability of cylinder machine boxboard, has related the extrapolated value of ink-film thickness at an impression of 0.001 in. to visual smoothness as measured by the Scheid smoothness tester.

Maynard and Newman (*21*) compared the Bendtsen, Bekk, and Talysurf instruments with subjective assessment of smoothness and found that the Bendtsen correlated best when using nine different papers, but that all three instruments correlated equally well with subjective smoothness when five slightly different sheets of the same paper were evaluated. This is similar to the conclusion of Fetsko (*10*) that several tests may be useful for quality control purposes but that no available empirical test for evaluating smoothness is applicable to all types of papers. For white patent-coated paperboard in letterpress printing of solids, the Sheffield and Bendtsen methods appear to offer the best compromises between the several requirements of routine control testing (*11*).

In studying coated paper requirements for high-speed letterpress printing, Glassman (*12*) found that the Hull red wipe (drawdown) test successfully differentiated differences between rolls of coated stock, whereas he was unable to detect these differences with the Chapman test. Glassman also found that, for the six papers studied, the surface roughness factor as measured by the Brush analyzer "yields data which are in agreement with press results insofar as smoothness of tone or fidelity of reproduction is concerned." Other recent literature in which nonair-leak methods of measuring smoothness are described include the work of Groult and Ramaz (*13*) (paper profile graphs, microscopic evaluation, printing tests, optical method, electrical capacitance method), of Clark (*9*) and of Ragan (*23*) (photo-techniques), of Apple (*5*) (friction meter), of Zentner (*35*) (bench model gravure press), and of Wink and Van den Akker (*34*) (nip-spreading device). In the latter paper the authors claim a "fair correlation" between Bekk smoothness for papers of low Bekk values and the surface roughness index as determined using the nip-spreading device. A progress report on investigation of smoothness using this device was recently presented by Sears (*25*).

T. W. LASHOF, Physicist, National Bureau of Standards, and JOHN MANDEL, Statistician, National Bureau of Standards.

* Members of the task committee: D. P. Antos, Jacqueline Fetsko, John Sulich, Jr., Leon Tyler, and T. W. Lashof, Chairman. This work has been supported, in part, by TAPPI Research Grants No. 143 and No. 171.

The principles and procedures for use and maintenance of several air-leak smoothness testers have been described in a number of recent papers: Bekk (*2, 8, 13, 26, 31, 32*), Gurley-Hill (*1, 8, 13, 28,*) Williams (*13*), Sheffield (*33*), Bendtsen (*8, 13, 14*), and a new Japanese instrument (*4, 15*). The latter appears to be similar in principle to the Sheffield and Bendtsen instruments. The new Karl Frank tester (*2*) appears to be similar in principle to the Bekk instrument. Anderson (*1*) describes three procedures for the evaluation of smoothness with the Gurley-Hill S-P-S tester. One of these is the proposed (*28*) TAPPI Suggested Method for flat shipping-sack kraft paper, a procedure which provides separate estimates of the smoothness of each side of the paper. The present (*27*) TAPPI Suggested Method for the use of the Gurley-Hill instrument yields only the total smoothness of the two sides.

The relative advantages and disadvantages of the Gurley-Hill, Williams, Bendtsen, and Bekk smoothness testers were evaluated by Groult and Ramaz (*13*), who concluded in favor of the Bekk which they recommended for adoption as a French standard. They pointed out that the Bekk test has been standardized in the United States, the Netherlands, Czechoslovakia, and the U.S.S.R. Groult and Ramaz reported that while the Bekk and Bendtsen values are inversely related and comparable, the Bekk tester is somewhat more "accurate" for papers of low and medium smoothness. Brecht and Geenen (*8*) found reasonably good correlation between Bekk (average both sides) and Gurley-Hill for Bekk values above 70 sec. and likewise between Bekk and Bendtsen for Bekk values below 250 sec. As previously reported (*17*), we found that 250 sec. was also the upper limit for correlation between the Bekk and Sheffield. Similarly, Horii (*15*) found a hyperbolic relationship between his instrument and the Bekk, but again the relationship did not hold for high Bekk values.

Groult and Ramaz reported coefficients of variation in the range 8 to 10% for both the Bekk and Bendtsen testers. Brecht and Geenen reported mean coefficients of variation of 13.9% for their Bekk tester and 17.3% for their Bendtsen. Antos (*3*) found a maximum coefficient of variation (for 3 materials) of 11.6% for the Sheffield instrument. We previously reported values for the Sheffield ranging from 1.2 to 27% (with a constant standard deviation of 6.0 units) and a mean value for the Bekk of 7.6% coefficient of variation (*17*). However, our values do not include machine and cross direction variations of the paper.

Brecht and Geenen agree with us that *sensitivity*. and not coefficient of variation, is the appropriate criterion for evaluating instrument performance.

Ranger (*24*), using the Bendtsen tester, studied the influence of paper permeability on air-leak smoothness measurements and found that it would give rise to large errors. His conclusions are generally applicable to all air-leak type smoothness testers. Tröger (*29, 30,*) investigated the effect of relative humidity variations on smoothness of stored paper, and the dependence of smoothness on temperature at 65% R.H. Bott (*6*) provided a theoretical explanation of Tröger's observation that the smoothness of paper increased with increasing temperature.

PRELIMINARY ROUND ROBIN

The preliminary round robin was twofold in purpose: first to acquaint the participants with the procedure and receive their critical comments, and second to obtain estimates of precision at the various levels of smoothness. Consequently, three materials were selected, covering the smoothness range of the mimeobond paper to be used in the main interlaboratory study (see below). For each material, two groups of eight specimens were sent to each participant. The numerical results were reported to the participants but are not presented here because of their preliminary nature.

Considerable laboratory-to-laboratory variability was noted for all three methods. Part of this was due to sampling error: the preliminary round robin was not designed to investigate the between-laboratory variability. However, part was due to the failure of some participants to follow the instructions, and, in the case of the Bekk method, the aforementioned TAPPI Standard. Several suggestions for improving the instructions were received. The instructions were revised to include these suggested changes and to emphasize steps in the procedure which were ignored or improperly executed. The revised instructions, as used in the main interlaboratory study, are appended to this paper.

A detailed statistical analysis appeared to show that the differences in results obtained by the various laboratories were consistent for different materials in the case of the Bekk method, but not for the Bendtsen and Sheffield methods. For the Sheffield method this was tentatively attributed to the fact that three separately calibrated scales are involved. For the Bendtsen method this was thought to be due, in part, to the use of at least two of the three manostats, and, in part, to the possibility that the relationship between results obtained with different manostats may depend upon the nature of the paper. Since only three materials were involved in this preliminary round robin, these conclusions and explanations must be considered to be highly speculative. It will be seen that the results of the main round robin, described below, fully support the original tentative conclusion for the Sheffield method. For the Bendtsen method, it will be seen that the difficulty associated with the manostats is apparently due, not to the nature of the paper, but to differences between Bendtsen instruments.

DESIGN OF MAIN INTERLABORATORY STUDY

One of the objectives of the smoothness study was the determination of the relationship, if any, between the results of the different methods. Since it is possible that the relationship changes for different classes of materials, the most mathematically exact relationship should exist for a single class of papers which differ only in smoothness. For this reason a special series of mimeobond papers were prepared from the same furnish. The furnish consisted of 80% bleached sulfite and 20% soda pulp to which was added 5% clay, 0.05% wax, and 1.5% dry rosin size. The series was prepared in the National Bureau of Standards experimental paper mill. As the paper was made, it was subjected to seven different finishing conditions at the machine calender stack, from antique (no calendering) to the maximum loading obtainable. Considering

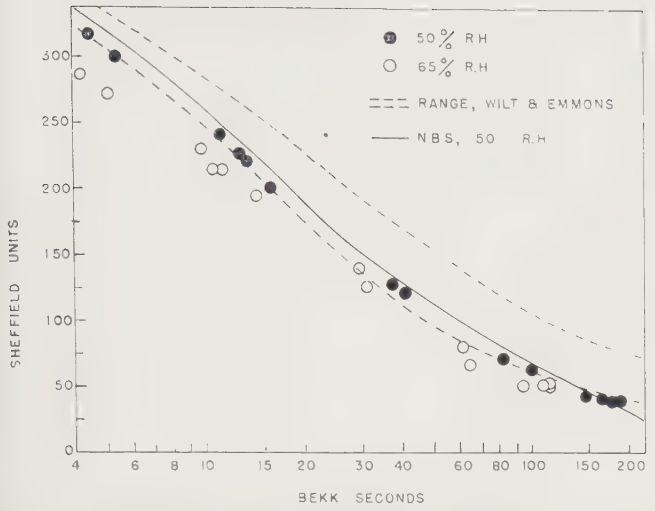


Fig. 1. Sheffield-Bekk relationship, showing possible effect of relative humidity. Circles are based on data from study reported here; solid line is from our previous paper (17); and dotted lines from paper by Wilt and Emmons (33). Relative humidity was not reported by Wilt and Emmons

both wire and top sides of the paper, this made a total of 14 different finishes, which ranged in value from 4.5 Bekk seconds to 180 Bekk seconds.

Because of the number of types of instruments in use and because of limited interest in any one class of paper, it was difficult to obtain enough participating laboratories for each method. For this reason it was necessary to restrict this study to just three methods: Bekk, Sheffield, and Bendtsen. Some laboratories had two instruments and some laboratories were able to provide two or more observers. Each observer was asked to run a complete set of tests on each available instrument. However, no laboratory was asked to contribute more than four instrument-operator combinations. In the remainder of this paper, the term "laboratory" will usually be construed to refer to each instrument-operator combination, whether in the same laboratory or not.

A total of 42 laboratories (in the sense defined above) participated in the study: 14 using the Bekk method, 17 the Sheffield method, and 11 the Bendtsen method.

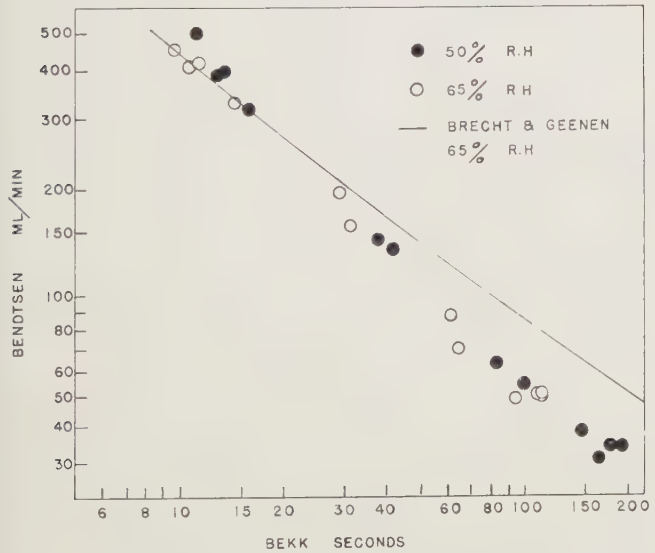


Fig. 2. Bendtsen-Bekk relationship, showing possible effect of relative humidity. Circles are based on data from study reported here; and solid line is from paper by Brecht and Geenen (8)

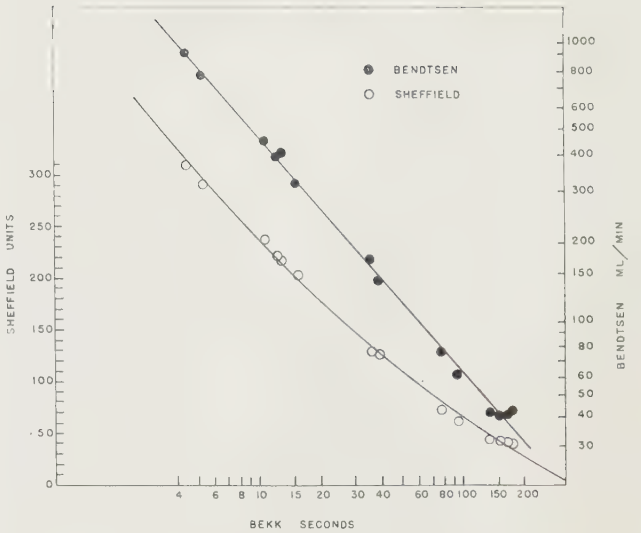


Fig. 3. Sheffield-Bekk and Bendtsen-Bekk relationships, ignoring effect of relative humidity

For each material eight consecutive sheets were selected. From each sheet 42 specimens were cut, 6 (cross direction) × 7 (machine direction). This arrangement actually meant that a sheet six specimens wide and 56 specimens long was used, which took advantage of the smaller machine direction variability. All 336 specimens were thoroughly mixed and eight specimens assigned at random to each of the 42 laboratories. The eight specimens of a particular material assigned to a particular laboratory were called a "group" of specimens. Each laboratory was thus allocated a group of eight specimens for each of the 14 materials. The 14 groups were arranged in a different random order for each laboratory. In addition, each laboratory was given one trial specimen for each material to be used in selecting the correct instrument settings, as described in the appended instructions.

The specimens were conditioned to the dry side, sealed in a moisture-vapor barrier material, and mailed along with instructions and data sheets to the participating laboratories.

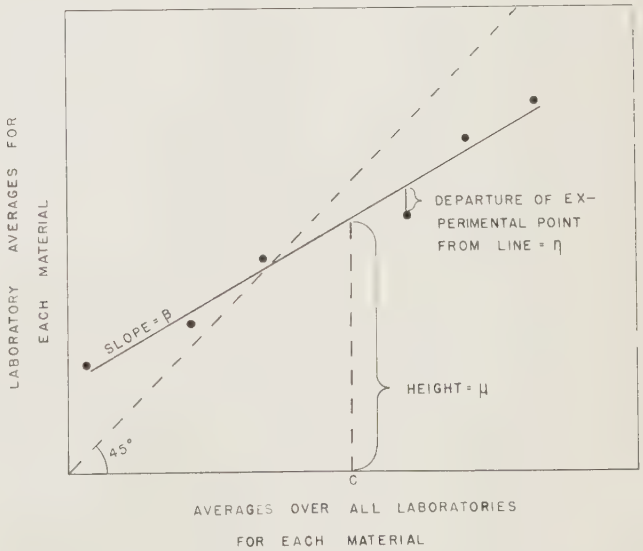

LABORATORY AVERAGES FOR EACH MATERIAL
DEPARTURE OF EXPERIMENTAL POINT FROM LINE = η
SLOPE = β
HEIGHT = μ
45°
C
AVERAGES OVER ALL LABORATORIES FOR EACH MATERIAL

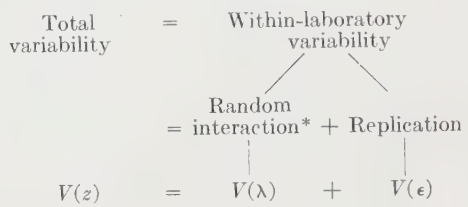
Fig. 4. Linear model. C = average of all materials and all laboratories. η may be divided into two parts: that which can be accounted for by replication error (ε) and that due to the differential response of that laboratory to that material (λ)

RESULTS

Relationships

As both laboratories using the TAPPI Standard condition of 50% R.H. and those using 65% R.H. participated in the interlaboratory study, it was possible to determine whether the relationship between methods depends on the relative humidity of the testing room. Figures 1 and 2 show the relationships for Sheffield versus Bekk and for Bendtsen versus Bekk, respectively. Also shown are the relationships found in individual laboratories and previously reported in the literature.

Between-laboratory variability is large (as will be seen below), and may be sufficient to explain the differences in the Sheffield versus Bekk relationships for 50 and 65% R.H. which are apparent in Fig. 1. The much smaller, if any, effect of humidity on the Bendtsen-Bekk relationship is definitely overshadowed by the between-laboratory variability.



Obviously a between-laboratory experiment is not the most efficient place to look for effects which could more easily be detected in one laboratory.

For the purpose of computing the relative sensitivities of the methods (see below), the differences in the relationships due to relative humidity, even if real, may be neglected. Using a modified least squares procedure which takes into account the fact that both variables are subject to error, relationships given below and illustrated in Fig. 3 were obtained.

$$y = 478.79 - 277.7x + 35.48x^2$$
$$z = 3.4790 - 0.7889x$$

where

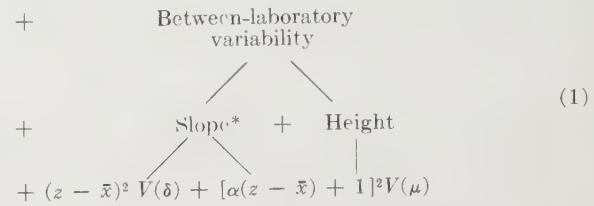
$x = \log_{10}$ Bekk, y = Sheffield
$z = \log_{10}(14.43 +$ Bendtsen)

Analysis of the Data

The purpose of the analysis of the data from the interlaboratory study is the segregation of the total error of each test method into its components. The analysis is based on the linear model of an interlaboratory study (*19*), which assumes that systematic differences exist between sets of measurements made by different "laboratories," and that these systematic differences are linear functions of the magnitude of the measurements.

Consider a particular laboratory and suppose that, for each material, the average value obtained by this laboratory is plotted against the average obtained for this material by all the laboratories combined. Then, according to the linear model, the points corresponding to the various materials will lie on a straight line except for random errors. The same applies for all the other laboratories. Thus the results of the round robin may be represented by a set of straight lines with common abscissas. Each laboratory is characterized by the slope β and the location parameter μ of its straight line, and the departure η of each experimental point from the line (Fig. 4).

The departure of an experimental point form its line (within-laboratory variability) may be divided into two parts: that explainable by replication error, ϵ, and that which is not, λ. The latter may be thought of as the differential response of that laboratory either to some interfering property of that material (such as permeability, or response to relative humidity), or as a result of instrument scale error. Hence, the total error of the test method may be considered to be composed of two within-laboratory components, λ and ϵ, and two between-laboratory components, β and μ. Since the latter may be correlated, this must be taken into account in the analysis. If the data are transformed so as to give a within-laboratory variance which is approximately independent of the magnitude of the measured quantity, the total variance, for any value of z in the transformed scale, is given by equation (1).



(1)

where

$V(\delta)$ = part of the variability of β not related to μ.
$\bar{x}$ = av. value of μ (see ref. *19*).

The first step in the analysis of the data was the determination of how the replication error varies with the magnitude of the measurement. Tables I through III show this information for the Bekk, Sheffield, and Bendtsen methods, respectively. In Table I there are 14 laboratories and 14 materials, making a total of 196 cells. For each cell, the average (top figure) and the standard deviation (bottom figure) of the eight replicate measurements are given. It is quite evident that the standard deviation increases with the average for the Bekk method as applied to the mimeobond papers included in this study. From the data reported here, the replication error is essentially proportional to the magnitude of the measurement in the case of the Bekk method but essentially constant and independent of the magnitude for the Sheffield method. Thus for the Bekk method the coefficient of variation is essentially constant, being 12.8%, while for the Sheffield method the standard deviation is 8.7 units. For the Bendtsen method neither the coefficient of variation nor the standard deviation may be considered to be reasonably constant, and it is necessary to use the more general assumption (*19*) of a linear relationship between the standard deviation and the value of a measurement. Thus for the Bendtsen method:

Standard deviation = 1.783 + 0.1236 × (Bendtsen value)

For high Bendtsen values, this gives a coefficient of variation of approximately 12.4%. This figure, as well as those for the Bekk and Sheffield methods, should be compared with those reported in the literature, see Table IV.

* In accordance with the linear model, the classical laboratory-material interaction is broken into two parts: a systematic effect characterized by differences in slopes and a random effect characterized by V(λ).

Table I. Bekk Smoothness, Showing Averages and Standard Deviations in Each Cell

The column averages of these quantities are also shown. Top figure of each pair is average, bottom is standard deviation. Laboratories marked (*) at 50% R.H.

Laboratories	*Materials* 2	10	3	4	9	12	13	5	1	7	8	6	11	14
1*	6.38	6.75	12.41	14.43	14.44	18.58	42.0	45.7	86.8	110.4	154.2	143.7	164.8	191.4
	1.14	0.56	1.55	1.59	2.37	2.46	9.2	5.7	6.0	20.1	8.8	24.7	17.3	17.8
2*	5.60	6.38	13.06	14.90	15.20	18.14	41.5	44.6	88.7	102.7	154.2	160.1	170.6	198.2
	0.81	0.47	2.19	1.34	1.15	1.94	4.3	5.3	13.7	25.2	14.8	34.8	14.8	16.1
3*	5.25	5.35	11.95	13.70	13.43	15.10	37.9	43.6	78.7	114.9	137.3	151.2	178.1	173.5
	0.75	1.39	1.97	1.33	1.53	4.31	7.5	4.7	11.2	23.2	7.5	25.3	13.2	23.7
4	4.46	5.55	10.33	11.41	12.21	15.73	32.8	33.1	64.8	76.3	106.9	122.5	124.6	124.2
	0.93	0.26	1.50	0.79	0.67	1.25	5.7	2.7	10.3	5.1	8.9	19.0	10.6	20.1
5*	4.01	5.88	11.73	13.41	12.70	16.16	40.6	41.7	91.3	100.4	167.0	207.1	207.0	201.0
	0.68	0.17	1.94	1.04	1.61	1.54	8.5	2.3	18.5	17.0	14.7	34.7	25.1	28.0
6	4.02	4.73	9.22	9.88	10.43	13.09	26.4	29.5	57.7	54.9	82.8	96.1	101.8	102.4
	0.52	0.09	1.60	0.88	0.96	0.65	5.2	1.3	2.6	8.5	7.3	16.8	15.0	16.8
7*	4.36	4.67	10.53	11.55	13.79	14.59	32.9	41.2	78.4	99.4	129.9	179.3	173.7	173.6
	0.71	0.30	1.75	1.31	1.48	1.70	4.6	4.3	10.2	17.0	8.8	29.7	11.4	24.3
8*	4.12	5.25	9.62	11.63	14.25	15.38	36.5	37.5	81.9	99.8	150.9	161.0	166.4	182.5
	0.64	0.46	1.85	1.41	1.91	1.19	4.4	4.4	10.8	15.7	16.2	24.6	14.3	27.9
9*	4.50	5.88	11.25	12.63	13.00	15.38	35.6	40.5	80.6	112.4	155.3	165.6	186.3	205.6
	0.54	0.35	1.04	0.74	1.51	1.41	7.1	4.1	8.6	17.9	12.6	15.4	13.8	19.6
10*	3.75	4.38	9.75	11.25	11.25	13.75	31.0	31.9	65.1	90.1	126.0	139.8	154.8	162.3
	0.71	0.52	1.39	0.71	1.58	1.28	6.6	4.7	5.8	19.7	14.9	23.4	12.9	17.0
11*	4.45	6.16	13.01	13.75	15.09	17.01	35.0	44.1	90.1	105.3	148.1	187.0	198.7	210.9
	0.74	0.46	1.88	0.75	1.93	1.81	8.0	4.5	9.9	18.8	13.5	32.8	20.2	37.9
12*	4.42	5.59	12.75	13.35	14.66	17.08	43.0	47.5	92.0	115.1	172.4	201.5	213.6	217.7
	0.62	0.95	1.66	1.50	2.67	2.10	5.2	7.4	14.6	36.9	22.8	31.5	11.0	28.4
13*	3.98	4.75	9.92	11.70	11.25	14.74	35.6	37.2	79.0	91.9	131.8	150.1	171.2	186.2
	0.43	0.25	1.51	1.80	1.43	0.96	4.6	3.2	9.7	1.7	16.6	25.0	20.2	20.3
14*	3.55	4.29	9.25	11.56	12.50	15.10	37.9	37.6	75.8	95.8	129.2	149.4	172.8	174.9
	0.46	0.20	1.26	1.32	1.11	1.31	8.4	3.5	9.2	18.1	9.6	15.2	14.8	15.2
Av. of 14 labs.	4.49	5.40	11.06	12.51	13.16	15.70	36.4	39.7	79.4	97.8	139.0	158.2	170.3	178.9
	0.69	0.46	1.65	1.18	1.56	1.71	6.4	4.2	10.1	17.5	12.6	25.2	15.3	22.4
*Av. of 12 labs. at 50% R. H.	4.53	5.44	11.27	12.82	13.46	15.92	37.6	41.1	82.4	103.2	146.3	166.3	179.8	189.8
	0.69	0.51	1.66	1.24	1.69	1.83	6.5	4.5	10.7	19.3	13.4	26.4	15.7	23.0

Table II. Sheffield Smoothness, Showing Averages and Standard Deviations in Each Cell

The column averages of these quantities are also shown. Top figure of each pair is average, bottom is standard deviation. Laboratories marked (*) at 50% R.H.

Laboratories	*Materials* 14	11	6	8	7	1	5	13	12	9	4	3	10	2
1	49.6	53.1	54.8	54.8	72.5	85.5	132.5	143.9	194.0	217.9	215.6	229.4	274.8	296.0
	7.4	4.3	7.5	5.2	7.8	8.4	8.9	15.2	11.3	7.7	7.1	9.9	11.5	20.3
2	52.4	53.8	49.8	54.5	65.4	84.4	131.5	139.0	202.0	216.1	218.9	237.1	273.4	283.8
	5.6	4.5	3.0	4.1	7.6	6.9	13.2	16.9	8.7	15.4	6.1	12.5	4.0	12.1
3	46.6	50.1	47.9	48.8	62.8	72.0	115.0	129.5	188.8	207.9	212.4	226.6	266.8	277.8
	3.7	6.5	6.7	4.6	8.3	7.4	10.6	21.2	9.5	13.5	12.8	13.5	8.0	11.6
4	47.4	50.1	52.5	44.3	64.9	74.5	120.0	146.1	194.0	216.5	218.0	223.8	269.4	287.4
	8.7	5.1	5.5	6.2	7.2	5.5	8.6	10.4	9.7	12.3	10.3	11.6	6.5	6.3
5	34.3	38.1	35.1	37.5	53.6	57.8	109.4	128.3	206.5	217.3	232.8	243.8	306.3	321.5
	3.8	7.2	3.9	3.8	12.8	7.2	9.2	21.9	9.6	14.3	6.1	8.9	3.8	3.0
6	37.8	30.4	33.9	33.5	51.4	74.4	120.1	125.4	201.8	223.0	229.4	248.8	298.6	310.0
	4.3	2.3	6.3	3.7	14.0	13.6	7.3	12.3	7.1	14.9	10.8	18.4	6.3	9.0
7*	33.0	34.4	36.5	39.4	69.4	78.8	121.9	126.9	201.9	219.4	222.5	232.5	286.9	305.6
	4.0	4.2	5.3	3.3	6.2	4.4	7.5	16.2	10.0	12.1	5.3	10.0	5.3	7.8
8*	35.3	35.6	34.0	40.3	66.3	70.0	118.1	118.8	195.0	215.0	220.0	231.3	288.8	308.8
	4.4	4.3	5.8	3.8	8.3	5.3	7.5	14.1	5.3	14.1	10.7	17.3	11.3	12.5
9*	46.1	48.6	48.6	51.5	63.0	73.9	113.0	137.5	207.6	225.8	231.3	243.8	304.6	318.6
	5.4	5.1	5.5	3.9	8.2	5.1	13.4	22.0	6.9	6.8	8.3	14.9	3.2	8.7
10*	48.9	45.3	46.9	45.1	66.5	79.8	125.3	131.0	206.5	217.6	234.8	242.0	306.6	322.5
	7.1	6.9	7.2	3.6	7.9	7.8	10.2	12.8	12.3	6.9	8.2	14.3	4.1	10.4
11	163.9	165.3	164.9	164.8	172.4	171.4	193.5	205.4	252.5	258.8	267.0	272.8	315.0	324.8
	2.2	3.2	2.9	2.2	2.8	5.3	6.1	7.6	6.2	9.2	7.2	7.6	3.1	6.3
12	164.4	164.3	163.9	166.9	60.8	174.6	195.1	201.9	253.5	263.1	268.8	272.5	320.0	336.4
	2.9	2.1	1.6	2.6	4.7	3.9	4.5	11.3	7.1	10.0	6.9	9.6	0.0	9.5
13*	36.4	36.6	43.9	44.5	62.1	67.5	118.1	127.5	210.0	235.0	238.8	247.5	295.0	317.5
	7.9	2.7	6.6	5.4	10.4	6.5	9.6	12.0	10.7	13.1	12.5	8.9	5.3	8.9
14*	45.4	38.5	43.0	44.1	66.1	76.9	126.9	141.4	206.3	226.9	230.0	247.5	307.5	321.3
	7.5	3.1	9.2	3.9	3.5	5.2	9.9	16.6	10.6	11.3	12.8	11.0	7.1	7.4
15*	40.1	41.0	42.6	44.0	64.6	74.4	129.5	126.5	203.8	225.0	233.8	245.6	305.6	333.1
	8.8	3.0	8.5	4.4	11.4	9.2	7.1	16.8	6.4	15.8	11.3	18.2	8.2	14.6
16*	35.0	36.0	36.8	38.0	51.9	59.3	112.1	115.4	193.4	212.8	212.9	237.8	292.5	308.0
	2.7	4.1	5.3	3.5	14.5	3.7	7.7	12.9	8.3	14.7	11.7	9.9	5.6	14.5
17*	35.7	33.1	37.2	36.2	54.0	66.8	115.9	110.8	193.0	208.5	218.2	241.4	299.3	316.3
	3.7	3.8	6.0	2.8	4.9	6.5	8.7	11.2	5.1	14.8	7.1	12.3	7.4	11.5
Av. of 17 labs.	56.0	56.1	57.2	58.1	68.7	84.8	129.3	138.5	206.5	223.9	229.7	242.6	294.8	311.1
	5.3	4.2	5.7	3.9	8.3	6.6	8.8	14.8	8.5	12.2	9.1	12.3	5.9	10.3
Av. of 15 labs. (omitting 11, 12)	41.6	41.6	42.9	43.8	62.3	73.0	120.6	129.9	200.3	219.0	224.6	238.6	291.7	308.5
	5.6	4.5	6.2	4.1	8.9	6.8	9.3	15.5	8.8	12.5	9.4	12.8	6.5	10.7
* Av. of 9 labs. at 50% R.H.	39.5	38.8	41.0	42.6	62.7	71.9	120.1	126.2	201.9	220.7	226.9	241.0	298.5	316.8
	5.7	4.1	6.6	3.8	8.4	6.0	9.1	15.0	8.4	12.2	9.8	13.0	6.4	10.7

Table III. Bendtsen Smoothness, Showing Averages and Standard Deviations in Each Cell

The column averages of these quantities are also shown for the nine laboratories using only the 150-mm. manostat for nine materials. Top figure of each pair is average, bottom is standard deviation.

Laboratory	Material 14	11	6	8	7	1	5	13	12	9	4	3	10	2
1	39.00	35.00	46.50	40.25	59.00	79.38	140.0	163.8	316.3	410.0	426.3	453.8	365.0*	471.3*
	6.61	4.81	8.93	6.61	9.94	20.47	13.09	39.26	15.06	57.57	43.40	41.38	9.26	33.99
2	53.13	54.00	53.63	51.63	85.38	89.50	158.8	208.1	350.0	438.8	398.8	430.0	350.6*	421.4*
	7.38	3.30	11.30	5.98	16.15	13.60	25.32	30.58	20.70	34.92	14.58	33.81	21.12	47.06
3	57.88	51.50	55.63	51.88	73.00	94.38	172.1	183.8	320.8	202.0*	397.5	233.0*	346.3*	413.8*
	8.81	9.78	7.84	3.76	12.92	16.63	18.80	16.64	32.69	31.73	34.95	19.03	24.02	34.62
4	50.88	58.00	58.00	50.38	72.63	92.25	158.8	207.5	354.4	445.0	201.9*	225.6*	371.3*	421.9*
	10.06	5.90	7.23	3.42	7.96	16.14	14.82	41.32	13.48	39.64	15.57	23.82	18.08	35.45
5	35.63	30.63	31.38	35.50	52.13	61.50	130.4	143.6	306.0	396.9	402.3	453.*m*	329.1*	433.5*
	7.09	6.44	6.37	2.98	13.29	7.77	13.19	28.22	25.11	24.07	39.76	..	17.30	41.60
6	32.00	31.63	29.25	37.13	52.00	58.13	130.1	144.1	316.9	393.1	356.3	422.5	360.0*	416.3*
	6.33	5.04	9.00	7.47	8.04	8.46	15.37	48.81	36.54	38.26	16.64	48.44	20.18	46.27
7	53.88	49.00	38.50	49.75	63.25	82.38	149.8	198.9	314.13	157.6*	159.3*	173.6*	293.3*	321.0*
	9.61	6.93	9.15	6.61	6.82	8.82	7.59	41.20	18.64	17.48	17.77	18.05	20.80	49.53
8	33.75	38.63	30.25	40.88	58.25	70.75	138.8	144.1	337.5	410.0	416.3	362.5‡	495.*m*‡	‡
	9.82	6.87	2.71	5.41	10.01	9.00	27.35	39.45	22.68	27.90	32.04	23.75	..	..
9	30.00	32.63	29.88	35.25	53.00	56.13	120.6	148.1	289.4	323.1	325.0	372.5*m*	..	..
	6.82	6.41	5.84	5.15	11.05	8.94	17.61	30.58	20.43	19.07	27.11	..	..	..
10	58.13†	58.13†	61.25†	39.38	55.00	115.6†	145.0	180.0	326.3	192.5*	187.5*	243.8*	368.8*	450.*m**
	16.68	5.94	11.88	9.80	7.07	9.80	25.63	37.80	33.78	19.82	13.89	29.25	17.27	..
11	63.13†	60.00†	60.00†	60.00†	93.75†	74.38	61.25*	86.25*	155.0*	20.25*	197.5*	225.0*	391.3*	420.*m**
	10.67	5.98	8.86	8.45	21.51	11.48	6.94	12.17	16.90	31.96	11.65	10.69	17.27	..
Av. of first 9 labs.	42.90	42.33	41.44	43.63	63.18	76.04	144.36	171.33	322.81					
	8.06	6.16	7.60	5.26	10.68	12.20	17.02	35.12	22.81					

* 75-mm. manostat; † 225-mm. manostat; ‡ 225-mm. manostat and 5 kg. weight; unmarked, 150-mm. manostat; *m* = median.

In order to continue with the analysis in accordance with the linear model, it was first necessary to transform the Bekk and Bentsen data so that in the transformed scales the standard deviations would be essentially independent of the magnitudes. The transformations used are given by the following equations, where y denotes a value in the original observed scale and z in the new scale:

Bekk: $z = 1000 \log_{10} y$
Sheffield: $z = y$
Bendtsen: $z = 1000 \log_e (1.783 + 0.1236y) - 1500$

For ease in discussion, the next steps in the analysis and the interpretation will be considered for each method separately.

Bekk Method

As a result of the transformation, the replication error ϵ is essentially independent of the magnitude of the measurement in the transformed scale, and has the following variance:

$$V(\epsilon) = \left(\frac{1000 \times 0.128}{2.30}\right)^2 = 3097$$

The next step in the analysis of the data consisted in locating the straight line corresponding to each laboratory. Table V and Fig. 5 show the results of the linear regression analysis. The table gives the parameters of the straight lines. The location parameter chosen is the ordinate of the centroid of the line, and for this table it has been transformed back to the observed scale for easier visualization.

The range in values for $V(\eta)$ is not excessive, and hence these values were pooled to give an average $V(\eta) = 619$ in the transformed scale. Part of the variability expressed by $V(\eta)$ is due to the replication error ϵ, namely, $V(\epsilon)/8$, since there were eight replications. Then:

$$V(\lambda) = V(\eta) - \frac{V(\epsilon)}{8}$$

$$= 619 - \frac{3097}{8} = 232$$

Figure 6 shows the amount and relative importance of the various sources of variability over the range of the measured quantity. Figure 6 is a graphical representation of equation (1). The ordinates are values of variance and the abscissas are Bekk smoothness values in the transformed scale. For convenience in interpreting, the corresponding coefficients of variation (%) and Bekk values (sec.) are shown. Since a simple logarithmic transformation was used, constant variance in the transformed scale corresponds to constant coefficient of variation in the original scale.

To use Fig. 6, divide the vertical distance labeled ϵ-

Table IV. Replication Error

Reference	Bekk, %	Bendtsen, %	Sheffield
Groult and Ramaz (*13*)	8–10	8–10	...
Brecht and Geenen (*8*)	13.9	17.3	...
Antos (*3*)	..	..	11.6%
Lashof, Mandel, and Worthington (*17*)[a]	7.6	..	1.2–27% = 6.0 units
Interlaboratory study	12.8	12.4	8.68 units

[a] The values do not include machine- and cross-direction variability.

Table V. Bekk Smoothness, Showing Estimates of the Parameters of the Straight Lines Corresponding to the Various Laboratories: β = slope, μ = ordinate of centroid, $V(\eta)$ = variance (fit) of points to straight line

Laboratory	μ	14 Laboratories β	14 Laboratories $V(\eta)$	12 Laboratories[a] β	12 Laboratories[a] $V(\eta)$
1	39.6	0.942	999	0.926	980
2	39.7	0.960	236	0.944	237
3	36.4	0.991	1282	0.974	1179
4	30.3	0.913	333	..	..
5	38.4	1.056	936	1.038	1025
6	25.3	0.881	619	..	..
7	34.5	1.028	819	1.010	827
8	34.9	1.028	613	1.010	643
9	37.0	1.028	564	1.010	483
10	30.8	1.021	308	1.003	277
11	39.0	1.015	872	0.998	881
12	40.5	1.056	209	1.038	232
13	33.2	1.035	253	1.017	278
14	32.8	1.048	623	1.030	676
Av. of 14 laboratories	34.9	1.000	619	..	..
Av. of 12 laboratories[a]	36.3	..	..	1.000	643

[a] At 50% R.H.

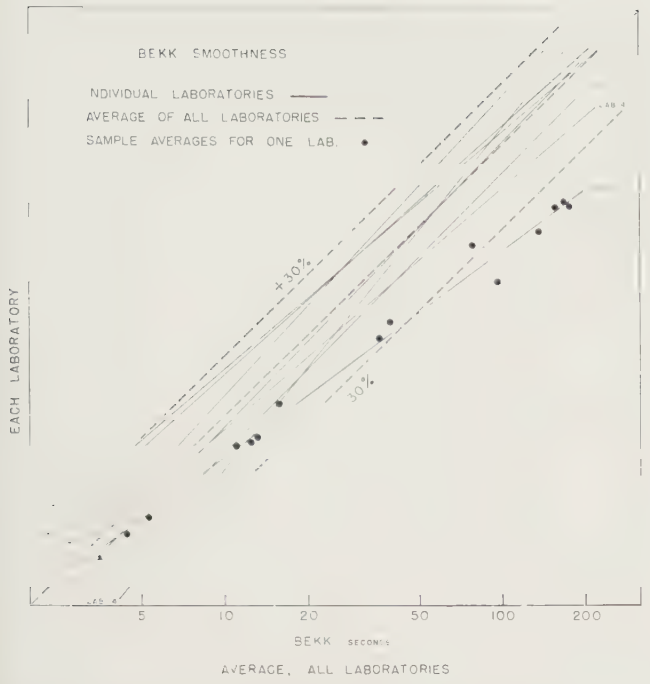


Fig. 5. Bekk smoothness, showing nonparallelism of the laboratory lines. The scale on both coordinate axes is logarithmic, but the vertical deviation of each point from the 45° line has been double in order to clearly show the differences between the laboratories. The broken lines correspond to deviations of ±30% from the average (45° line). A few of the laboratories close to the 45° line have been omitted for clarity. The material averages are shown for one laboratory for which the fit of the points to the line is typical

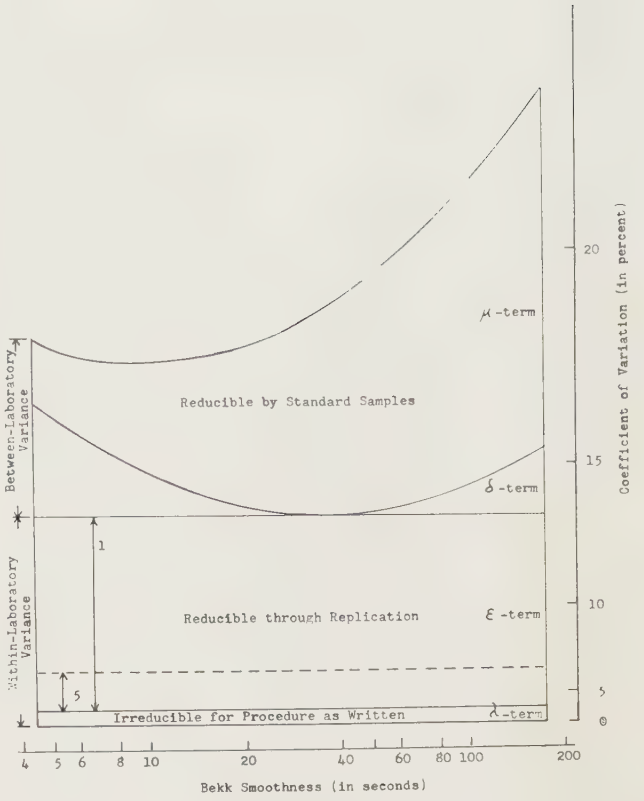


Fig. 6. Sources of variability in the Bekk smoothness method when applied to a special series of mimeobond papers. Based on data from 14 laboratories, including two at 65% R.H. and twelve at 50% R.H.

term by the number of replications, then, starting from the bottom of the figure, construct for each value of Bekk smoothness a vertical segment equal to the sum of the vertical distances corresponding to the λ-term, the modified ϵ-term, the δ-term, and the μ-term. The top point of this segment is then read off on the scale labeled "coefficient of variation" to give the total variability expressed as coefficient of variation. The terms in δ and μ are omitted in this construction when standard samples are used. The λ-term represents the ultimate limit of the method as written, and it is seen to be approximately 3% coefficient of variation.

Interpretation of the Analysis of the Bekk Method

(1) Comparison of $V(\lambda)$ with $V(\epsilon)$ reveals that $V(\lambda)$ is quite small, by a factor of 15, approximately, and that therefore an effective increase in precision will result from replication. The number of replications should not appreciably exceed 15, since the limiting factor, at that point, is $V(\lambda)$ which is unaffected by replication.

It might have been expected that $V(\lambda)$ would be small for these data, since it will be remembered that $V(\lambda)$ reflects the differential response of the laboratories to some interfering property of the material or to instrument scale error. Since the same furnish was used for all materials in this study, and the materials differed only in finish, any interfering property (such as permeability) should be functionally related to finish; hence, the response of a laboratory to the interfering property should be functionally related to the laboratory's response to the finish. Thus, while the laboratory line may be shifted due to the interfering property, individual points for different materials should lie close to the line (assuming instrument scale error be negligible).

The above discussion indicates that while 15 replications may be useful in improving precision when comparing Bekk smoothness values of papers with extremely similar furnishes run on the same paper machine, further studies will have to be made to justify this many replications when furnishes are only moderately similar or different machines are used.

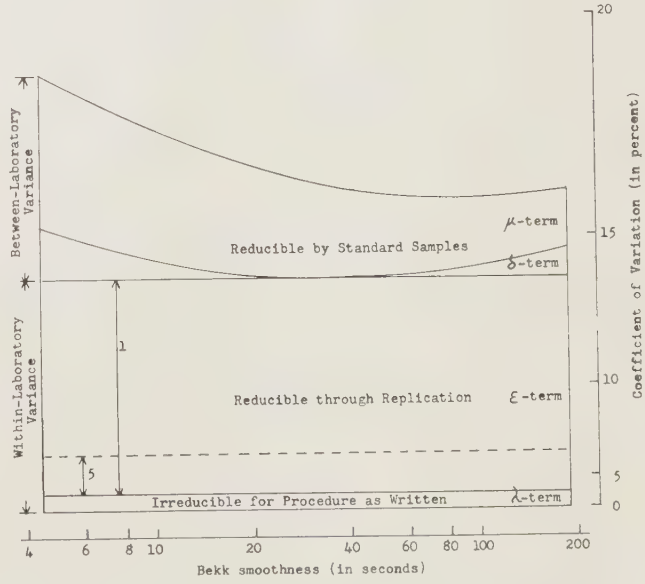


Fig. 7. Same as Fig. 6, except based on data from 12 laboratories all at, or near 50% R.H.

(2) Study of Table V shows that laboratories 4 and 6 have low values of β and μ. These two laboratories used 65% R.H. conditions while all of the others operated near 50% R.H. This may be the explanation of the low values obtained by these laboratories. It is not necessary to omit these laboratories when the analysis is made using the linear model. However, since it was known that these laboratories differed appreciably in their procedure from the TAPPI Standard, the entire analysis was repeated omitting laboratories 4 and 6. Figure 7 and the two right columns of Table V show the results of the re-computation. Comparison of Figs. 6 and 7 shows that differences in relative humidity make a big contribution to between-laboratory variability, which is to be expected.

Different observers using the same Bekk instrument appear to obtain approximately the same values of μ and β, but possibly different values of $V(\eta)$, as can be seen from Table V when it is mentioned that "laboratories" 1, 2, and 3 used the same instrument, 11 and 12 another, and 13 and 14 a third instrument, and all of the other "laboratories" used different instruments and observers. However, the evidence for this observation is not very strong and the conclusion must therefore be considered tentative: one might, in fact, expect different values of μ and β for different observers, depending on their skill in avoiding parallax and in operating a stop watch.

(3) The importance of between-laboratory variability as compared to within-laboratory variability can be determined from Fig. 6 or 7. It is seen that if only one measurement is made, the "replication" error, ϵ, overshadows all of the other sources of variability in Fig. 7. However, the present TAPPI Standard calls for five replications per side. Since the average of five measurements has one-fifth the replication variance of a single measurement, the within-laboratory variability of averages of five is small compared with the between-laboratory variability.

It will be noted that the term in $V(\delta)$ is appreciable even in Fig. 7, indicating that the laboratory lines crisscross more or less at random, which can be seen in Fig. 5. Therefore, in calibrating the method, two calibration points will be required. The variation in the term in $V(\mu)$ for different values of the measured quantity indicates that the lines partially converge (Fig. 5). The calibration points therefore, must, be carefully located to avoid the area of convergence.

In summary, as many as 15 replications may be worth while in reducing the within-laboratory variability of the Bekk method. Even if only five replications are used, as in the existing TAPPI Standard, the between-laboratory variability becomes obvious. In order to reduce the between-laboratory variability, the method must have better standardization, which may be accomplished by refinement of the apparatus or procedure but which may be more easily accomplished by using two standard samples to calibrate the method at appropriately chosen values of the measured quantity.

Sheffield Method

It is quite obvious from just a glance at Table II that the data of the "laboratories" numbered 11 and 12 (actually two observers in the same laboratory) should be omitted from the analysis. We have not been able to determine why these two laboratories differ so considerably from the others, but suspect that they made a serious error in the standardization of the second rotameter column.

Table VI. Sheffield Smoothness, Showing Estimates of the Parameters of the Straight Lines Corresponding to the Various Laboratories: β = slope, μ = Ordinate of Centroid, $V(\eta)$ = Variance (fit) of Points to Straight Line

Laboratory	μ	*15 Laboratories* β	*15 Laboratories* $V(\eta)$	*9 Laboratories* β	*9 Laboratories* $V(\eta)$
1	148.2	0.896	22.4		
2	147.3	.897	33.0		
3	139.5	.886	12.0		
4	143.5	.904	43.5		
5	144.4	1.081	23.7		
6	144.2	1.058	18.3		
7	143.5	1.000	26.2	0.970	28.8
8	141.2	1.005	15.8	0.975	8.8
9	151.0	1.022	22.3	0.991	25.4
10	151.3	1.025	18.1	0.994	12.4
13	148.6	1.055	27.4	1.023	35.0
14	151.5	1.043	9.9	1.012	15.4
15	150.7	1.062	21.1	1.030	11.9
16	138.7	1.024	19.0	0.993	14.7
17	140.4	1.042	37.6	1.012	24.4
Av. of 15 labs.	145.6	1.000	23.4	..	..
Av. of 9 labs.[a]	146.3	..	..	1.000	19.6

[a] At 50% R.H.

Table VI shows the results of the linear regression analysis after omitting the two, obviously discrepant laboratories. Again, some of the laboratories operated at other than 50% R.H. These were omitted for the second set of results shown in Table VI. The range in values for $V(\eta)$ is not excessive in either set, and hence the average values given at the bottom of the columns may be used in computing $V(\lambda)$, following the procedure used above for the Bekk method. $V(\epsilon)$ is obtained from Table II. For $V(\epsilon)$ we use the square of the average of all standard deviations for all materials and all laboratories included in the analysis.

All 15 laboratories: $V(\epsilon) = 75.28$, $V(\lambda) = 13.94$
Nine laboratories at 50% R.H.: $V(\epsilon) = 72.38$, $V(\lambda) = 10.59$

Figures 8 and 9 show the relative importance of the various sources of variability for all laboratories and for just the 50% R.H. laboratories, respectively. Note that in this case the standard deviation is independent of the magnitude of the smoothness reading, and this is indicated by the scale on the right.

Interpretation of the Analysis of the Sheffield Method

(1) Comparison of $V(\lambda)$ with $V(\epsilon)$ reveals that $V(\lambda)$ is a somewhat larger fraction of $V(\epsilon)$ than was found for the Bekk method. Since the instrument used with the Sheffield method has three columns which are separately adjusted against standard orifices, poor adjustment would result in poor agreement between columns. In the language of the linear model, the data for each column might be fitted very well with a segment of a straight line, but the three segments would not necessarily be aligned, and therefore if a single line is fitted for all columns simultaneously the fit is apt to be quite poor. For this reason the analysis was repeated using only the six roughest materials for which every laboratory used column 1. In this case $V(\epsilon)$ increases slightly (to 101.76) but $V(\lambda)$ vanishes, indicating that the high value of $V(\lambda)$ found when all

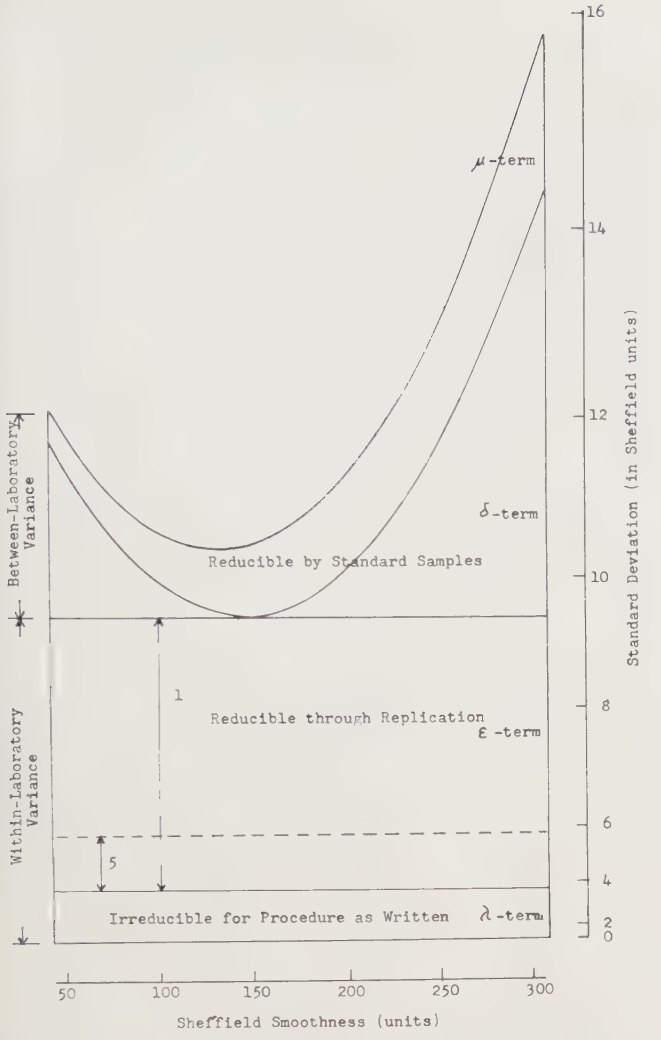


Fig. 8. Sources of variability in the Sheffield smoothness method when applied to a special series of mimeobond papers. Based on data from 15 laboratories, including four at 65% R.H., nine at 50% R.H., and two not reporting R.H.

three columns are used is very likely due to the poorness of adjustment of the columns to each other.

(2) The first four "laboratories" in Table VI operated at 65% R.H. Laboratories 5 and 6 did not report relative humidity. The other laboratories worked at or near 50% R.H. As can be seen from the table, the 65%-R.H. laboratories have low values for the slope β. Unfortunately, all sets run at 65% R.H. were actually run in a single laboratory (but with different instruments). Consequently, the difference that is apparently associated with relative humidity may actually be a mere laboratory bias. However, in view of the fact that the Bekk smoothness results show a similar effect, the effect may be real.

The same instrument was used by each observer in the following pairs of "laboratories": 1, 2; 3, 4; 9, 10; 14,15; 16,17. The same observer was involved in each member of the pairs: 1, 3; 2, 4; and 5, 6. There appears to be better agreement between different observers using the same instrument, or between instruments when used by the same observer, or even between two instruments operated by different observers in the same company (laboratories 7 and 8) than between unrelated laboratories.

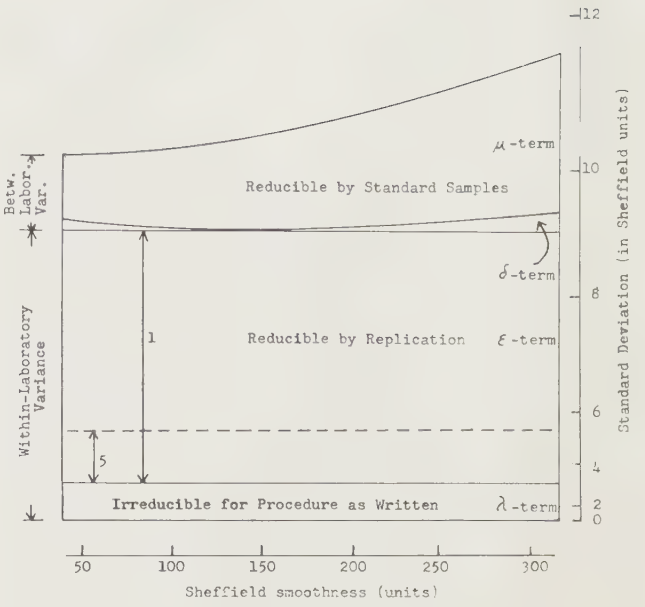


Fig. 9. Same as Fig. 8, except based on data from nine laboratories, all at or near 50% R.H.

(3) Figures 8 and 9 reveal the importance of between-laboratory variability. The appreciable decrease in between-laboratory variability when the analysis is restricted to laboratories operating at or near TAPPI Standard conditions of 50% R.H. (Fig. 9) may be fortuitous because of the small number of independent laboratories involved in these analyses or may be associated with the use of compressed air which might have a more erratic effect for 65% R.H. conditions than for 50% R.H. (*17*). It is $V(\delta)$, the random part of the slopes of the laboratory lines, which all but disappears in Fig. 9.

In summary, there is poor agreement between ranges in the Sheffield method, indicating that more attention must be paid to the adjustments of the columns to the standard orifices. Newer instruments appear to have improved valves which should make the adjustment easier. Also the simplified adjustment procedure suggested in reference (*17*) coupled with a very careful initial adjustment should allow easier maintenance of a correct adjustment once it is obtained. Despite the use of standard orifices in the adjustment of the instrument, the Sheffield method will still need at least one standard sample to calibrate for what might be noninstrument differences between laboratories.

Bendtsen Method

As was already noted in the preliminary round robin, it is necessary to use at least two of the three manostats to cover the range of smoothness of the mimeobond paper used in these studies. The procedure recommended to the participants in the round robin calls for the use of the 150-mm. manostat whenever possible. A reading obtained when using this manostat is considered to be in standard Bendtsen units, or "Bendtsen Figure." To obtain the Bendtsen Figure when using the 75-mm. manostat, the manufacturer of the principal instrument required by this method has recommended that the factor 2.4 be used. For the 225-mm. manostat the recommended factor is 0.5. For a perfectly incompressible material it would seem

Table VII. Bendtsen Smoothness: Use of Linear Model to Determine Best Ratio for Converting to Bendtsen Figure (9 Laboratories, 14 Materials)

Ratio for 75-mm. manostat	*Ratio for 225-mm. manostat*	$V(\lambda)$
2.4	0.5	3285
2.25	0.575	1776
2.2	0.6	1540
2.15	0.625	1435
2.1	0.65	1457

that the factors should be exactly proportional to the pressure ratio, namely 150/75 = 2.0 and 150/225 = 0.67, respectively, since the rate of air-leakage through a capillary should be proportional to the difference in pressure between the ends of the capillary. Therefore, when in preliminary studies of this instrument, a ratio of about 2.1 was obtained with mimeobond paper when using the 150 and 75-mm. manostats, a question was raised on whether the ratio 2.4 should apply to all materials, or whether the ratio should depend on the compressibility of the material. Therefore, in the initial analysis of the data, that to determine the dependence of standard deviation on the magnitude of the measurement, only readings obtained with the 150-mm. manostat were used (see Table III). The resulting transformation required to stabilize the within-cell variances has been given above.

Two procedures were followed in an attempt to find the correct ratios to use with mimeobond paper. First, if we assume that the linear model is a valid way of representing an interlaboratory round robin, the correct pair of ratios will be that pair which minimizes $V(\lambda)$; that is, when a number of pairs of ratios for the 75 and 225-mm. manostats are used, that pair which gives the best fit of the laboratory lines to the experimental points should be the most nearly correct pair. The results of this approach are given in Table VII, from which it can be seen that the best ratio for the 75-mm. manostat lies between 2.1 and 2.15. A detailed comparison of the laboratory values of $V(\eta)$, which includes $V(\lambda)$, indicates, however, that a low ratio does not give best fits for all laboratories. Thus it appears that the ratio may vary from laboratory to laboratory. Accepting this hypothesis, it is possible to select the optimum ratio for each individual laboratory, as that ratio which leads to the smallest $V(\eta)$. The results of this procedure are shown in Table VIII in the penultimate column.

In the second approach, six groups, of nine specimens each, were sent to every laboratory. Actually only three materials were included, one group of each material to be tested using the 150-mm. manostat and one using the 75-mm. manostat. The results are given in Table VIII. It is obvious that the ratio does indeed vary from laboratory to laboratory and that the values for the ratios inferred from the linear-model analysis are in good agreement with those obtained in the more direct approach (with the exception of laboratory 3

Table VIII. Bendtsen Smoothness: Determination of Ratio for Converting to Bendtsen Figure

Laboratory	*Relative humidity, %*	*Material*	*75-mm. manostat*	*150-mm. manostat*	*Ratio*	*Average ratio*	*95% confidence limits*	*Ratio from linear model analysis*	*Optimum ratio from combined evidence*
1	65	3	208	463	2.23	2.16	...	2.1	2.10
		4	184	398	2.16				
		9	189	393	2.08				
2	..	..	..	..	..	..	...	2.1	2.06
3	65	3	225	T[b]	>2.22	?	...	2.1	2.06
		4	176	T	>2.84				
		9	182	T	>2.75				
4	65	3	215	451	2.09	2.11	...	2.1	2.11
		4	185	390	2.11				
		9	209	442	2.12				
5	50	3	[a]	428	..	..	...	2.4	2.4
		4	[a]	374	..				
		9	[a]	384	..				
6	..	..	..	..	..	..	...	2.1	2.3
7	65	3	153	421	2.75	2.63	...	2.4	2.55
		4	128	336	2.62				
		9	141	357	2.52				
8	?	3	209	458	2.19	2.20	...	..	..
		4	[a]	398	..				
		9	181	401	2.21				
9	50	3	208	407	1.96	2.06	...	..	..
		4	179	358	2.01				
		9	164	361	2.20				
10	..	..	..	..	..	..	...	2.15	2.07
11	50	3	232	447	1.92	2.09	...	2.15	2.09
		4	178	387	2.17				
		9	177	383	2.17				
12	50	3	205	T[c]	..	2.27	...		
		4	171	351	2.05				
		9	168	418	2.49				
NBS	50	3	211	453	2.15	2.17	2.09 to 2.26		
		4	180	396	2.20				
		9	186	403	2.17				
NBS	65	3	229	457	1.99	2.04	1.94 to 2.14		
		4	182	395	2.17				
		9	211	419	1.98				

[a] All tests made with 150-mm. manostat.
[b] T = Reading beyond top of scale.
[c] Eight tests made with 75-mm. manostat.
Note: Lab. 2 used the same instrument as Lab. 3; Lab. 5, same instrument as Lab. 6; and Lab. 10, same instrument as Lab. 11.

Table IX. Bendtsen Smoothness, Showing Estimates of the Parameters of the Straight Lines Corresponding to Various Laboratories: β = Slope, μ = Ordinate of Centroid, $V(\eta)$ = Variance (Fit) of Points to Straight Line

Laboratory	9 Laboratories, 14 Materials μ	β	$V(\eta)$	11 Laboratories, 12 Materials μ	β	$V(\eta)$
1	165	1.030	3220	122	1.012	4050
2	185	0.917	2690	143	0.908	3550
3	183	0.910	1520	142	0.904	1990
4	189	0.938	2180	145	0.932	2930
5[a]	152	1.096	2360	111	1.075	1780
6[a]	147	1.086	3820	107	1.056	2830
7	172	0.951	4590	132	0.948	5150
8[a]	..	..	..	120	1.096	9430
9[b]	..	..	..	102	1.010	2290
10[c]	164	1.035	1730	122	1.032	1730
11[c]	165	1.036	1240	123	1.026	1570
Av.	169	1.000	2590	124	1.000	3390

[a] 50% R.H. [b] 55% R.H. [c] 59% R.H. Others at 65% R.H.

which is discussed below). Relative humidity has a small effect on the ratio, as is shown by the results from the National Bureau of Standards. The major effect appears to be instrumental in its origin, since two observers using the same instrument generally obtain the same ratio. Also, data received from the manufacturer of the instrument show that the ratio does not change appreciably for a wide range of materials. The differences which have been found between nominally equivalent manostats (*7*, *8*) appear to be too small to account for the differences in ratio, and therefore the source of the ratio variability needs further exploration.

Laboratory 3 (see Table VIII) indicated that all readings using the 150-mm. manostat were beyond the top of the scale. Such a situation would indicate that the ratio for this laboratory would be very high, which does not agree with this laboratory's results from the linear model analysis. During the NBS study, it was noticed that the rotor occasionally stuck in the top of the rotameter column, and it is believed that this may account for the results reported from laboratory 3. The ratios used in the final linear model analysis are shown in the last column of Table VIII. They were obtained by combining the information from the initial linear model analysis and from the direct approach into a tentative set of ratios, and then running a second series of linear model analyses from which the final set of ratios were selected.

Table IX shows the results of the linear regression analysis. It was not desirable to run separate analyses for the two relative humidities, because too few laboratories were available. Because two of the laboratories indicated that they obtained off-scale values for two of the materials, the analysis was run two ways: first, by omitting the two laboratories and, second, by omitting the two materials.

The values of $V(\epsilon)$ and $V(\lambda)$ resulting from these two analyses are given below:

All 11 laboratories, 12 materials: $V(\epsilon) = 13{,}293$, $V(\lambda) = 1730$

Nine laboratories (omitting laboratories 8 and 9), 14 materials: $V(\epsilon) = 11{,}877$, $V(\lambda) = 1108$

Figure 10 shows the relative importance of the various sources of variability for all laboratories (12 materials). An almost identical figure was obtained for the nine laboratories and 14 materials. Note that in this case neither the coefficient of variation (as for the Bekk method) nor the standard deviation (as for the Sheffield method) is independent of the smoothness magnitude. The scale for coefficient of variation is indicated by the dashed lines.

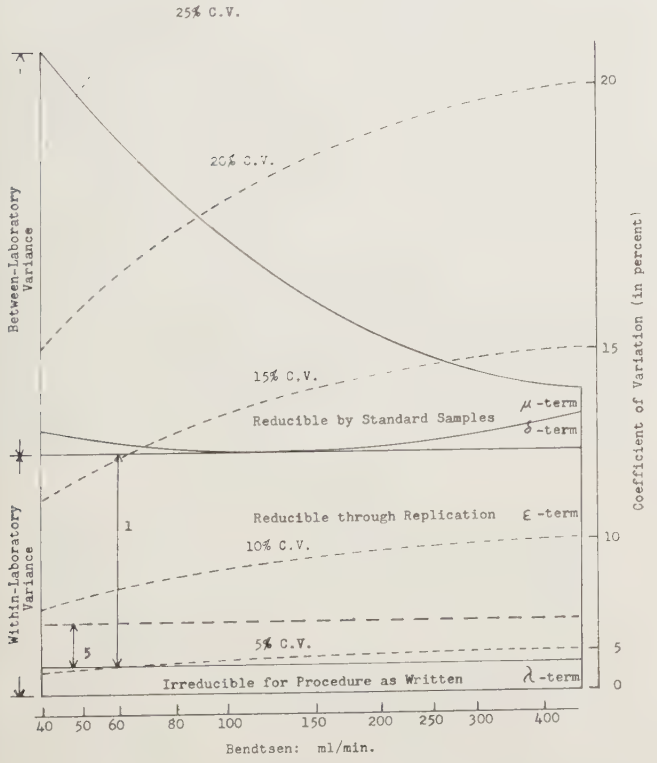


Fig. 10. Sources of variability in the Bendtsen smoothness method when applied to a special series of mimeobond papers. Based on data from 11 laboratories, including five at 65% R.H., two at 59% R.H., one at 55% R.H., and three at 50% R.H.

Interpretation of the Analysis of the Bendtsen Method

(1) While $V(\lambda)$ is a larger fraction of $V(\epsilon)$ than was found for the Bekk method, it is somewhat smaller than was found for the Sheffield method. However, even this moderately low value was obtained for the Bendtsen method only after minimizing V(λ) by adjusting the scale ratios separately for each laboratory. The final value of $V(\lambda) = 1108$ for nine laboratories and all 14 materials should be compared with the values for $V(\lambda)$ given in Table VII.

(2) Examination of Table IX indicates that μ is generally larger and β is generally smaller for the laboratories operating at 65% R.H. Since so few independent laboratories are involved, this effect may be only fortuitous; however, it must be considered as a possibility.

(3) The very considerable between-laboratory variability for low Bendtsen figures shown in Fig. 10 may be due to relative humidity, as just mentioned.

Finally, the most definite conclusion that can be drawn with respect to the Bendtsen method is the conclusion that the ratio for different manostats is not the same for all laboratories. This ratio seems to depend primarily on the instrument, only slightly on relative humidity, and perhaps not at all on the observer.

RATIO OF SENSITIVITIES

Two methods for measuring the same property may

Table X. Number of Sheffield and Bendtsen Observations Which Can Be Made in Same Time as Five Bekk Observations

Bekk value, sec.	*No. of Bekk observations*	*No. of Sheffield or Bendtsen observations*
4.4	5	7
9.2	5	10
19.1	5	16
40.0	5	29
83.5	5	57
174.3	5	113

be compared by comparing the sensitivities of the methods (*20*). This requires a knowledge of the relationship between the methods, and of the standard deviations of each method as a function of the magnitude of the measured quantity. When the two methods are being compared for use within one laboratory, the standard deviations should be derived from the within-laboratory variability, $V(\lambda) + V(\epsilon)$. When the two methods are being compared for use in a specification or for any other interlaboratory purpose, the standard deviation to be used is the square root of the total variance, $V(z)$ given in equation (1). In both of these cases, however, $V(\epsilon)$ is to be replaced by $V(\epsilon') = V(\epsilon)/n$, where n is the number of replications called for by the method or specification.

The present TAPPI Standard T 479 sm-48 calls for five replications for the Bekk method. For the Sheffield and Bendtsen methods, we will follow the procedure of Brecht and Geenen (*8*) and use not five replications but the number of replications that will require the same total testing time. Based on the information provided by Brecht and Geenen, the number (n) of specimens which can be tested using the Bendtsen method while five specimens are tested using the Bekk is given by the following equation:

$$n = \frac{5(10 + 1.25B)}{10} \qquad \text{(nearest smaller integer)}$$

where B is the Bekk reading in seconds; 25% of B is allowed for the fall of the mercury column to the starting point, and 10 sec. are allowed in both methods for the change of specimens and observation and recording of reading. Since the Sheffield methods should require approximately the same testing time as the Bendtsen, the same equation will be used for the Sheffield. Values of n, for a few selected values of Bekk smoothness, are given in Table X.

The sensitivity ratios of Sheffield versus Bekk and of Bendtsen versus Bekk are shown in Fig. 11. These curves are for the total variances given in Figs. 6, 8, and 10. The solid curve in each figure is based upon the above considerations as to the number of replications. The dashed curve is based on 10 replications for the Sheffield or Bendtsen against five for the Bekk. As might be expected, there is little practical advantage in making more than 10 replications, and the large numbers or replications indicated in Table X are both unreasonable and unnecessary even though they can be run in the same time as for fewer Bekk readings. This will be the case even when standard samples are used to reduce the effect of the between-laboratory variability, because then, $V(\lambda)$ will be the limiting factor. It is seen that the Sheffield and Bendtsen

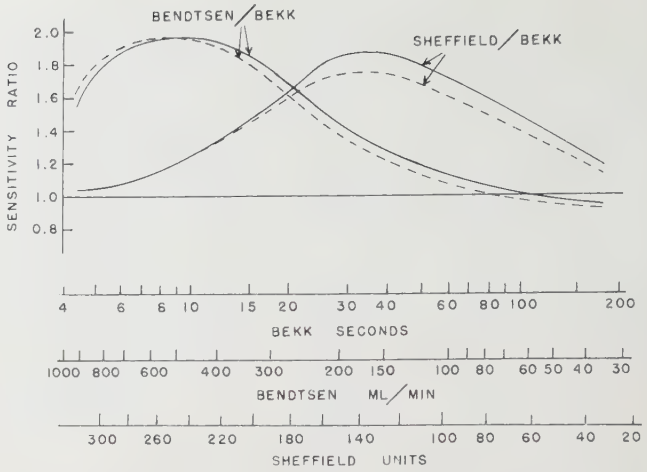


Fig. 11. Sensitivity ratios for the Bendtsen versus the Bekk method and for the Sheffield versus the Bekk method. The solid curves are for the number of replications given in Table X, while the dashed curves are for ten Bendtsen or Sheffield replications versus five Bekk replications

methods are slightly more sensitive over most of the range than the Bekk method.

DISCUSSION

It appears that each of the methods for measurement of smoothness considered in this paper need further study and improvement. Also, it appears that standard samples will help in reducing the differences between laboratories, and this may be all that is necessary, particularly in the case of the Bekk method. The Sheffield method requires more care in adjustment of the scales to the standard orifices, a procedure which should be made easier by recent improvements in the Sheffield instrument. Until further improvements are made in the instrument, each user of the Bendtsen method must determine his own ratio when different manostats are used.

The linear model of the measuring process appears to be a very useful basis for the analysis of an interlaboratory study. Unfortunately, while the number of instrument-operator combinations used in this study was not unduly small, the number of actual laboratories involved was not sufficient to provide definitive information on the methods. The sources of some of the large differences between laboratories are suggested by the analysis, but definite conclusions on which method or methods should be included in TAPPI Standards must await the completion of another interlaboratory study now being planned which will involve many more laboratories for each method.

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Received Nov. 2, 1959. Presented in part at the Ninth Testing Conference in Savannah, Ga., Sept. 30–Oct. 3, 1958, and in part at the 44th Annual Meeting in New York, N. Y., Feb. 23–26, 1959.

The authors and members of the committee wish to thank the many people who have contributed to this study: the members of the Paper Testing and Graphic Arts Committees for their suggestions and encouragement, the manufacturers of the instruments for their cooperation, Martin J. O'Leary and the National Bureau of Standards paper mill staff for the preparation of the mimeobond paper, Vernon Worthington for the tedious job of cutting, randomizing, and packaging specimens, Mary Nan Steel for assistance in the computations, Carol Dannemiller for programming the analysis for the IBM 704, and the many participants in the round robin work for their time, effort, and careful following of instructions.

APPENDIX

INSTRUCTIONS USED IN INTERLABORATORY STUDIES

Bekk Smoothness

Follow the method outlined in TAPPI Suggested Method T 479 sm-48, but with the following exceptions and precautions.

Apparatus

Adjustment and Calibration. Carefully follow T 479 sm-48 and especially the portion pertaining to the cleaning of the tube and the softness of the rubber diaphragm. The mercury must be clean.

Test Specimens

The test specimens for the round-robin test are provided and are already cut to size for the test. The package containing the specimens must be opened in a TAPPI Standard conditioning room,* and the specimens conditioned for at least 48 hr. (The specimens will have been preconditioned to about 50% of the standard moisture content before shipping.) Handle the specimens with care and test them in the order received.

The test specimens are separated into groups by colored boards. The initial specimen in each group is marked "XX." This specimen is to be used to determine which stopcock position should be used in testing the remaining specimens of the group.

Note: Follow T 479 sm-48 in selecting the stopcock position and the timing marks (i.e., marks between which the fall of the mercury column is timed).

Procedure

The marked side of the specimen is the side to be tested, i.e., the side to be placed face-down in contact with the polished glass surface. Make the test with the stopcock in the position indicated by the pretest on the "XX" specimen.

Record the readings directly on the data sheet supplied to the nearest 0.1 sec. (or as close as the stop watch or electric stop clock can be read).

Sheffield Smoothness

Apparatus

The apparatus shall consist of:

1. A smoothness gage in which the paper specimen is held against a flat glass plate under a head through which air is directed. The head shall weigh 1640 ± 1 g. and shall have two concentric annular lands of total area 0.150 ± 0.005 sq. in. and with each land 0.015 + 0.0005-in. wide. The lands shall be made of or finished with a corrosion-resistant material (e.g., stainless steel or chrome plating.) The air shall enter through an orifice in the head so as to fill the annular groove between the lands, and escape across the surface of the paper under the lands. Each smoothness gage shall be equipped with built-in orifices to be used as standards in adjusting the flowmeter.

2. An air flowmeter of the float type, consisting of adjustable pressure regulators, tapered glass columns with floats, and a mercury manometer.

3. A source of compressed air (60 to 135 p.s.i.), filter, and primary regulator.

Initial Adjustment and Calibration. Connect the inlet side of the filter to the air supply, and the outlet side to the primary regulator, and connect the outlet side of the primary regulator to the inlet side of the air flowmeter. Adjust the primary regulator to 30 p.s.i. and tighten the locking nut.

Turn the flowmeter regulator handles to thele ft until they are loose. Insert the manometer plug into the output coupling of the first column and adjust the corresponding regulator until the mercury manometer reads 1.50 p.s.i. Repeat for the other

* 50 ± 2% R.H. and 23 ± 2°C.

columns. Wait for at least one-half hour, then check pressure in each column and readjust.

Connect the output coupling of the first column to the no. 1 coupling on the smoothness gage. Adjust the float *positioning* knob at the top of the column until float rests at the upper red line. Place the finger over the no. 1 orifice on the smoothness gage. The float should drop to come to rest at the lower red line. If the spread is too great, turn the *amplification* adjustment knob at the bottom of the column to the left, or if the spread is too small, increase the amplification by turning the knob to the right. Recheck upper float position and adjust positioning knob if necessary; recheck lower float position and adjust amplification knob if necessary; repeat until float comes to rest opposite the upper red line when orifice is open, and opposite lower red line when finger closes orifice.

Follow the above procedure for each of the columns. Then check the pressure in each column and reset to 1.50 p.s.i. if necessary. Re-check upper and lower float positioning in each column. Repeat until no further adjustments of pressure, position, or amplification are necessary. The tester is now in calibration and ready for use.

Check the upper and lower float positioning regularly during use, more frequently for the first few hours after the air supply is turned on, less frequently when the tester is in continuous use. If adjustment appears necessary after the initial adjustment and calibration, the abbreviated adjustment described in the next paragraph will usually be sufficient to again bring the tester into calibration.

Abbreviated Adjustment and Calibration. After the initial adjustment, the smoothness tester may drift out of calibration. This drift is generally due to changes in the pressure regulators. Hence, only the regulators should need adjustment. The pressure regulator for each column should be adjusted, however, not to obtain the correct pressure but to obtain the correct float position.

In order to adjust by the abbreviated method, connect the output coupling of the first column to the no. 1 coupling on the smoothness gage. Adjust the *pressure* regulator for the first column until the float rests at the upper red line. It will then be found that the amplification needs little or no adjustment and the pressure is very nearly correct. Repeat for the other columns.

Maintenance. Drain the filter of accumulated oil and water at least daily.

If the floats tend to stick in the columns due to dirt or static charges, remove and clean the columns in accordance with the manufacturer's instructions.

Handle the gaging head with care at all times, as rust, nicks, or dirt will cause erroneous readings. When not in use, lower the head onto a piece of rust-inhibiting paper. Keep the glass plate free from dirt and scratches. Do not insert wires or other objects in the standard orifices except as noted below.

Column Overlap Check Test. Check the accuracy of the orifices as follows. The readings obtained on the first column should be the same (a) when connected to orifice no. 1 and the finger is placed over this orifice, and (b) when connected to orifice no. 2 (no finger). This comparison between (a) and (b) may also be made on the second column. Furthermore, the readings obtained on the second column should be the same (c) when connected to orifice no. 2 and the finger is placed over this orifice, and (d) when connected to orifice no. 3 (no finger). The comparison between (c) and (d) may also be made on the third column. When any discrepancies exist, first try to clean the orifices by blowing them out with compressed air. If this is not sufficient to insure proper overlap, use a little solvent before blowing them out. As a last resort, the solvent and a *careful* reaming out of the side orifices with a pen cleaning wire should be sufficient.

Test Specimens

The test specimens for the round-robin test are provided and are already cut to size for the test. The package containing the specimens must be opened in a TAPPI Standard conditioning room,* and the specimens conditioned for at least 48 hr. (The specimens will have been preconditioned to about 50% of the standard moisture content before shipping.) Handle the specimens with care and test them in the order received.

The test specimens are separated into groups by colored boards. The initial specimen in each group is marked "XX." This specimen is to be used to determine which column of the flowmeter should be used in testing the remaining specimens of the group.

Procedure

Connect the center (unnumbered) coupling of the smoothness gage to the coupling for no. 3 column of the flowmeter, exactly the same as if preparing to test a low reading (high smoothness) paper. Lower the gaging head gently onto the glass plate, with no specimen in place, and record the resulting reading as zero check. Be sure the glass and gaging surfaces are clean. If necessary, wipe them with a soft chamois.

Connect the center (unnumbered) coupling of the smoothness gage to the output coupling of the flowmeter as indicated by tests on the "XX" specimen of each group. Test the remaining specimens of the group without changing these connections.

Raise the gaging head. Insert the specimen, with the side to be tested (i.e., the marked side) face upward, between the gaging head and the glass plate. Lower the gaging head gently onto the specimen, and observe the behavior of the float.

If the float drops to a position on scale, record the position. If the float drops to a position on scale but then drifts from the position, record the float position at the instant when the float pauses in its downward motion.

Record the readings directly on the data sheet supplied to the nearest Sheffield unit.

If the float drops clear to the bottom (B) of the column or if the float remains in the top (T) of the column, record this information as B or T. Set this specimen aside until all of the specimens of its group have been tested. Then change the coupling connections, so that a reading on this specimen may be obtained. Record this reading next to the previously recorded B or T.

* 50 ± 2% R. H. and 23 ± 2°C.

Apparatus

The apparatus shall consist of:

1. A smoothness gage which shall consist of a bell weighing 264 ± 0.15 g. and having an annular land 0.15 ± 0.001 mm. wide and 100 ± 0.2 mm. in circumference. The land shall be made of or finished with a corrosion-resistant material (e.g., stainless steel or chrome plating). Provision shall be made for air to enter through the side of the bell. In use, the land of the smoothness gage will rest on the paper, and the air from within the bell will escape across the surface of the paper under the land.

2. An air flowmeter of the float type, consisting of two rotameter tubes for the ranges 0 to 150 and 50 to 500 ml. per min., respectively, and provided with interchangeable manostat weights for maintaining the air pressure at 75, 150, and 225 mm. of water pressure, respectively.

3. A plane ground glass plate upon which the paper specimen is placed.

4. A compressor for giving an air flow free of oil content, a coiled up, rubber hose of sufficient length to damp out compressor ripples, and a pinchcock for regulating the flow of air from the compressor.

5. A capillary gage for verifying the adjustment of the rotameter tubes when unpacking the instrument.

Initial Adjustment and Calibration. Mount the instrument on a stable foundation (heavy table, bench, etc.) in a place with minimum vibration, and level by means of the two leveling screws. Place the compressor on the floor or on another bench, so that no vibrations from the compressor can reach the instrument. Connect the compressor through the coiled-up length of rubber hose to flowmeter, and connect the flowmeter to the smoothness gage in accordance with the manufacturer's instructions.

Caution: Do not place the manostat weight on the tester unless the air supply is working, and do not start or interrupt the air supply while a manostat weight is in place on the manostat shaft.

Connect the capillary gage to the flowmeter at the nipple connection intended for the porosity gage and set the switching cock for passage of air through this outlet. Start the compressor. Set the other switching cock so that the more sensitive (0 to 150 ml. per min.) rotameter tube is in use. Also adjust the pinch cock on the hose leading from the compressor so that with the 150-mm. water-pressure manostat in place, the manostat will rotate slowly but smoothly.

In case the rotor is not rotating in the rotameter tube, readjust the level of the flowmeter (within the range of the control circle of the spirit level) until the rotor is turning with maximum speed. When the rotor is rotating smoothly, note the scale reading corresponding to the upper edge of the rotor. This figure should correspond within 3% to the figure printed on the capillary gage. Agreement indicates that there was no damage to the instrument in transport.

Now set the switching cock for passage of air to the smoothness gage. Place the smoothness gage carefully and lightly on the glass plate. The rotameter tube should give a zero reading.

Care and Maintenance. Scratching the glass plate and knocking the smoothness gage against the table or plate must be avoided, as otherwise the sensitive steel land of the gage will be damaged and false readings will result. When not in use, the smoothness gage should be kept in its special housing box which is fitted with an impregnated bottom cover to prevent corrosion of the land.

The manostat weights are dynamically balanced and must therefore be handled with care. Do *not* lubricate them.

Regularly check hose connections and hoses for leaks, including the hoses behind the rear cover of the flowmeter.

If the rotor tends to stick, remove and clean the tubes in accordance with the manufacturer's instructions.

Test Specimens

The test specimens for the round-robin test are provided and are already cut to size for the test. The package containing the specimens must be opened in a TAPPI Standard conditioning room,* and the specimens conditioned for at least 48 hr. (The specimens will have been preconditioned to about 50% of the standard moisture content before shipping.) Handle the specimens with care and test them in the order indicated on the data sheet.

The test specimens are separated into groups by colored boards. The initial specimen in each group is marked "XX." This specimen is to be used to determine which manostat and which column of the flowmeter should be used in testing the remaining specimens of the group.

Procedure

Set the switching cock for passage of air to the smoothness gage, and set the other switching cock to the 0 to 150 ml. per min. rotameter tube. Use the 150-mm. water pressure manostat. Place the gage gently on the glass plate, with no specimen in place, and record the resulting reading as zero check. Be sure the glass and gaging surfaces are clean. If necessary, wipe them with a soft chamois.

With the first ("XX") specimen of each group, determine the rotameter column and the manostat to be used. (Normally the 150-mm. water-pressure manostat will be used, but if necessary to obtain readings, the 75 or 225-mm. manostat may be used.) Test the remaining specimens of the group without changing the settings. Place the specimen with the side to be tested (i.e., the marked side) face upward on the glass plate, and center the smoothness gage gently on the specimen, and observe the behavior of the float.

If the float drops to a position on scale, record the position. Record the readings directly on the data sheet supplied to the nearest ml. per min.

If the float drops clear to the bottom (B) of the column or if the float remains in the top (T) of the column, record this information as B or T. Set this specimen aside until all of the specimens of its group have been tested. Then change the column or manostat as required, so that a reading on this specimen may be obtained. Record this reading next to the previously recorded B or T.

* 50 ± 2% R. H. and 23 ± 2°C.

Measurement of the Contribution of Fluorescence to the Brightness of Papers Treated with Whitening Agents*

F. GRUM and T. WIGHTMAN

It is shown that a Beckman DK-2 Spectroreflectometer can be modified and used for the measurement of the brightness of samples containing optical bleaches which fluoresce. The samples, placed at the reflectance position of the instrument, are illuminated with completely diffuse illumination. Light from a source of controlled spectral distribution is directed into the integrating sphere through the opening ordinarily used for the detector, so that the integrating sphere illuminates the sample with completely diffuse light. A "characteristic-vector" method is compared with integration with the $\bar{z}$ color-mixture function of the CIE system, for evaluation of the "brightening" effects of optical bleaches.

UNDYED papers and white pigments have nearly flat spectrophotometric reflectance curves except for a sharp decrease of reflectance toward short wavelengths in the blue spectral region. The greater the decrease in reflectance in this region, the yellower the paper and the less satisfactory it is as a "white." Because of this fact, measurement of spectral reflectance is a reliable way to determine the whiteness of nearly white materials so long as dyes are not used for the improvement of the whiteness. Many methods have been used to improve the whiteness of paper. Addition of various dyes is quite common. If a blue dye is added to pulp in order to improve the whiteness of the paper, it introduces a problem in evaluation. These problems and a method for evaluation of whiteness of the material without and with dye additions has been described by MacAdam (*1*).

Recently, chemical manufacturers have made available "optical bleaches" or fluorescent "brighteners" for paper. We shall follow the customary usage and refer to the combined subjective effects of reflectance and radiation from such fluorescent additives as "brightness." Two samples—one of which contains an optical bleach; the other without—which appear equally bright under the same illumination, are considered to have equal brightness. The problem is to establish a physical method of measurement which will correctly indicate the equality of brightness of such pairs. Optical bleaches, today widely used as brightening agents, are rarely themselves white. They cause tints that are as noticeable as those caused by blue dyes. The amounts of brightening agents that can be used, therefore, are limited in the same way as the amounts of blue dye that can be used to produce white.

Our objectives are not to specify which brightening agents are most effective, nor to specify how the brightening agents are applied to the paper pulp, nor to discuss the most suitable concentrations.

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* Communication No. 2042 from the Kodak Research Laboratories.

These problems and methods are very well described by Harkavy and Carr (*2*).

The objectives are:

1. To describe a method of testing paper and fabric materials containing optical bleaches.
2. To evaluate the apparent brightness measured by the new method.

THE MEASUREMENTS OF BRIGHTNESS

As stated earlier, the measurement of brightness when fluorescent brighteners are present in a material is quite complicated and creates many problems. Numerous factors have to be considered, such as the appropriate light source, the appropriate receptor, and the emission characteristics of the brightener used. If only the amount of fluorescence on an arbitrary scale is to be measured, then almost any radiometer in which the light source has a sufficient portion of its energy in the ultraviolet region is suitable. The fluorescent radiation is a function of the spectral energy distribution of the ultraviolet component of the illuminant. An instrument such as a Lumetron or a Fluorimeter is suitable to measure the fluorescence. They have mercury-vapor sources and suitable filters to protect the sample from visible radiation. However, if a mercury line is used to irradiate a sample containing an optical bleach, the bleach may or may not be properly excited. Hence, such an instrument may be used only as means for comparing samples treated with the same brightening agent.

Although the human eye is a very good detector of small color differences, in many cases better than a visual spectrophotometer, it is essential to have a physical means to measure and discriminate small brightness differences in order to establish some kind of tolerance limits and to evaluate the efficiency of a particular brightening agent.

Instruments such as the Sweet brightness meter, the Alinco brightness tester, and the Zeiss Elrepho are capable of measuring the reflectance of the samples treated with optical bleaches. All these instruments operate on the same principle—they illuminate the sample at 90° and measure the light reflected at 45°. Since none of these instruments is equipped with a monochromator, it is necessary to use some appropriate filter in front of the receptor, and no complete spectrophotometric curve can be obtained by use of them.

BRIGHTNESS MEASUREMENT WITH THE BECKMAN DK-2 SPECTROREFLECTOMETER

When the reflectance of samples containing optical bleaches is measured with a General Electric recording spectrophotometer or with similar instruments, the results do not correctly indicate the visual appearance.

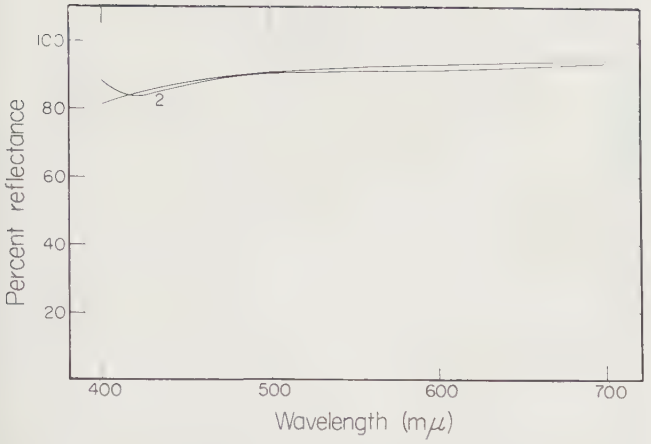

Fig. 1. Spectral reflectance curves measured on General Electric recording spectrophotometer: 1, Sample without optical bleach; 2, sample with optical bleach

Samples which were found to be brighter visually had equal or even smaller reflectance values than those visually less bright. Such an example is shown in Fig. 1, where the reflectances, measured on the General Electric spectrophotometer, show little difference, yet one sample appears visually much brighter than the other. In many cases the samples found visually brighter have lower reflectance than less bright samples. From such results it was concluded that a spectrophotometer suitable for measuring the brightness of samples treated with optical bleaches must provide a means by which undispersed white light having substantial ultraviolet content is incident on the sample. The Beckman DK-2 spectroreflectometer can be modified to fulfill this requirement and to respond properly to the presence of fluorescent brightening agents. With the modification of the optical system, this instrument is capable of measuring the spectral distribution of the fluorescent light emitted by the sample.

The modification of the optical system shown in Fig. 2 was achieved in the following manner:

1. The detector (a 1P28 photomultiplier tube) was removed from its normal position and mounted at the rear of the instrument in the position normally occupied by the light source. An adapter which properly positions the detector at the rear of the instrument can be

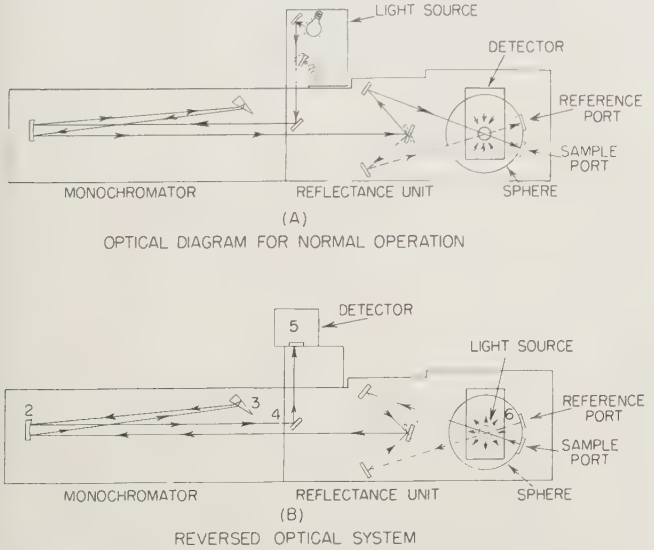

Fig. 2. Diagram of optical path of Beckman DK-2 spectroreflectometer: (A) Normal; (B) reversed

Fig. 3. Photograph of instrument arrangement

obtained on special order from Beckman Instruments Inc.

2. An incandescent lamp was mounted at the top of the integrating sphere in the position normally occupied by the detector. In such a position the light source illuminates the sphere through the normal detector opening. The sphere itself is utilized as a diffuser so that the samples are illuminated with diffuse illumination, which is essential if the results are to be accurate. The advantage of diffuse illumination is that no surface correction for the samples is needed and the orientation of the sample is immaterial.

3. An appropriate housing was built around the light source on top of the integrating sphere to prevent other light from entering the system. This housing and the general arrangement of the instrument are shown in Fig. 3.

4. A current and/or voltage-regulated power supply is required for the light source.

The light source used was an 18-amp., 6-v., T10 bulb, C-8 filament General Electric tungsten filament projection lamp operated at a prescribed current to produce a color temperature of 3000°K. Fluorescent brighteners can cause very noticeable tint changes under varying qualities of illumination; therefore, a controlled light source is imperative.

The integrating sphere of the instrument serves a

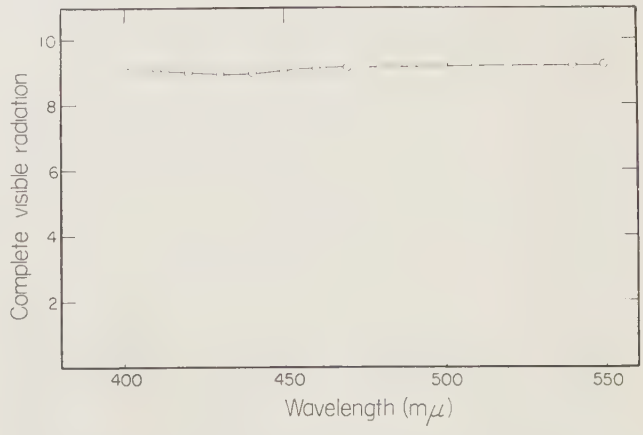

Fig. 4. Vitrolite standard measured on Beckman DK-2 spectroreflectometer with reversed optical system and National Bureau of Standards certified values

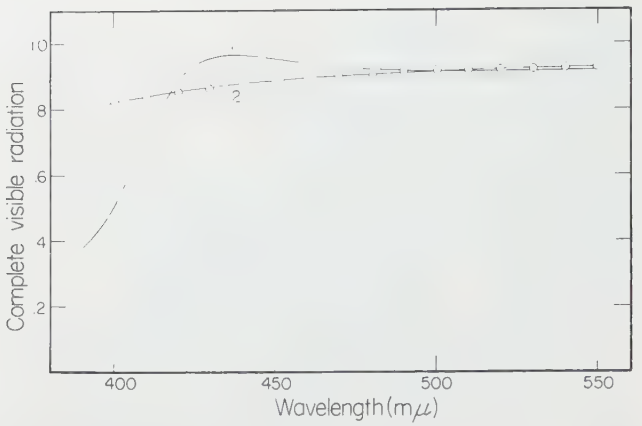

Fig. 5. Visible radiation curves: 1, Sample treated with optical bleach; 2, sample not treated with optical bleach; O, General Electric recording spectrophotometer reflectance values for nontreated sample

very important function. The walls of the sphere are coated with magnesium oxide. With the modifications just described, the samples are illuminated diffusely with white light, which has sufficient ultraviolet energy to excite any fluorescence present in the sample. The optical path of the instrument is reversed (Fig. 2B). The light reflected and emitted from the sample is dispersed and measured.

If the fluorescence alone has to be determined, then the energy entering the integrating sphere must be limited to wavelengths below that of the fluorescent light to be studied.* However, for the evaluation of brightness, the sample should be irradiated with unfiltered light from the source in order to excite the sample properly. The amount of radiation from the sample at each wavelength is recorded directly as a continuous curve on the instrument recorder. This radiation is the sum of the fluorescence and reflectance from a sample, and for the purpose of this paper, will be called "complete radiation."

In order to obtain results on an absolute basis, the instrument was calibrated and normalized at 100% for a magnesium oxide standard white. The MgO standard whites were carefully prepared and were checked against a National Bureau of Standards calibrated

* Stokes' law: Wavelengths emitted by a fluorescing system must be longer and contain less energy than the absorbed light of shorter wavelengths.

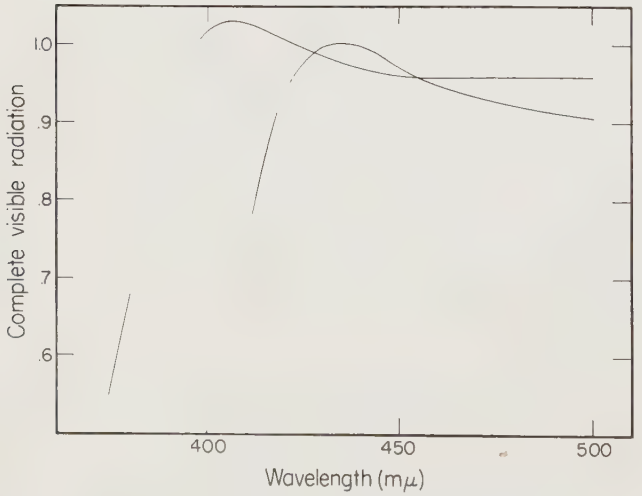

Fig. 6. Visible radiation curves of two different paper stocks treated with different optical bleaches

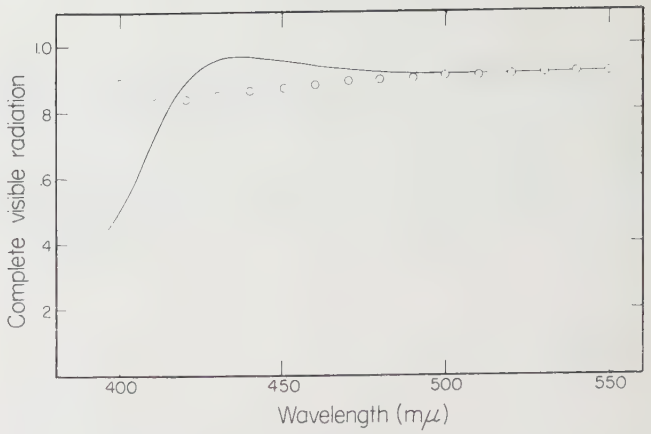

Fig. 7. Visible radiation measured with reversed optical system. O, Reflectance values

Vitrolite tile. Judd (*3*) recommended magnesium oxide to be used as a standard, perfect white. To check the validity of this procedure and the results obtained therewith, a sample of a white paper, which was free from any fluorescing agent, was measured on the instrument with these optical arrangements. Since no fluorescent material was incorporated in the sample, the result should indicate only spectral reflectance. The same sample was therefore measured on the General Electric spectrophotometer. The results agree very well with the results obtained on the Beckman DK-2 spectroreflectometer with the reversed optical system. The accuracy of the results is shown in Fig. 4. The Vitrolite tile was measured with the reversed optical system on the DK-2 instrument and the values certified by the National Bureau of Standards were also plotted on the graph. The deviations from the certified values of reflectance were not greater than 0.2%.

The total radiation can be higher than 100% because the 100% basis is the reference of the nonfluorescent magnesium oxide.

DISCUSSION OF RESULTS

Figure 5 shows two curves. Curve 1 represents the total radiation from a sample treated with a certain brightening agent, and curve 2 represents the total radiation from a paper made from the same pulp without the optical bleach. Consequently, the second curve is identical with the normal spectral reflectance curve. Figure 6 shows values for two different paper stocks

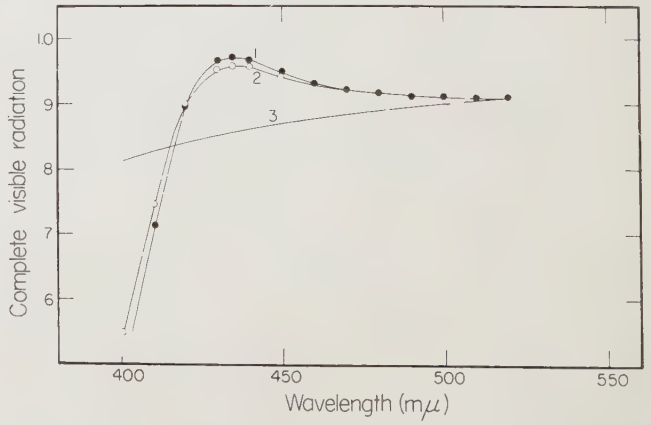

Fig. 8. Visible radiation (curves 1 and 2) from the same pulp with different amounts of optical bleach and (curve 3) the same pulp with no optical bleach. Dots represent vector reconstitution using equation (1)

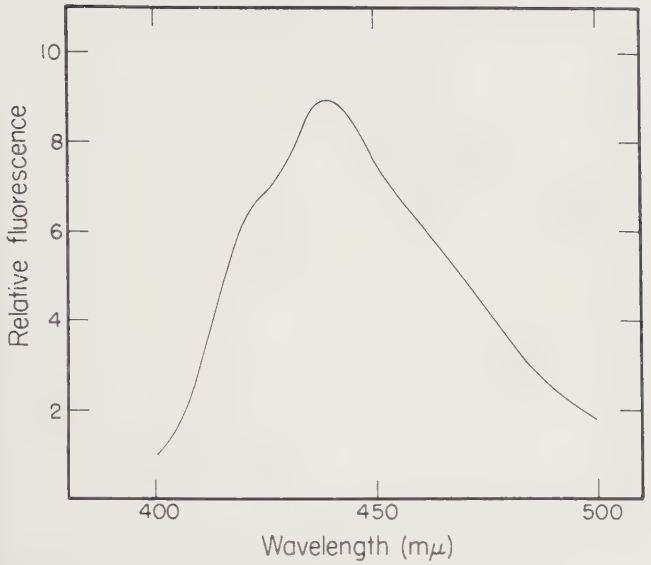

Fig. 9. Relative fluorescence of optical bleach used on samples in Fig. 8

treated with different brightening agents. The solid curve in Fig. 7 shows the complete radiation obtained on the Beckman DK-2 instrument with the reversed optical system, in comparison with results (shown by points) obtained with the original arrangement for measuring only the reflectance values. Figure 8 shows curves for two samples, both made from the same pulp, but treated with different amounts of brightening agent. Figure 9 represents the relative fluorescence curve of the brightening agent used on the samples in Fig. 8. Figure 10 shows how the complete radiation results are affected if the ultraviolet component of the light source is diminished by filtering. If the ultraviolet light is completely eliminated, as shown by the complete radiation curve 3, the results are almost indistinguishable from the normal reflectance curve or from the complete radiation curve of a sample not treated with any brightening agent.

Interpretation of Results

Over 200 samples, treated with a great variety of optical bleaches, were measured by the reverse optical system on the Beckman DK-2 spectroreflectometer and the complete radiation was determined. In all cases the results agree with the visual observations,

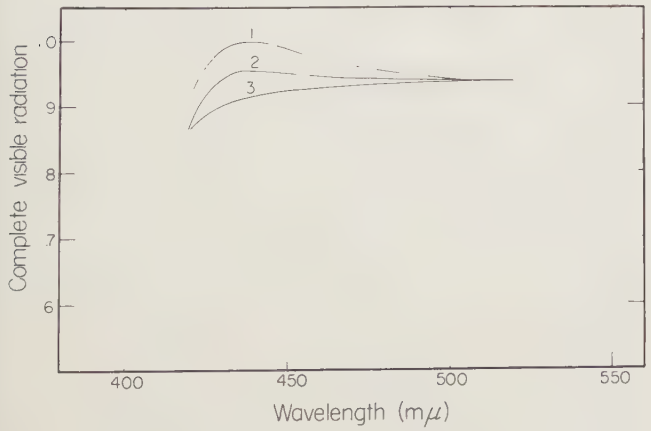

Fig. 10. Effect of the ultraviolet component of the light source on the visible radiation: 1, With all the ultraviolet energy of the source; 2, with 30% ultraviolet energy removed; 3, with all ultraviolet energy removed

which indicate that the method described is valid and suitable for evaluating the brightness of samples containing chemicals which fluoresce. It remains now to express the measured results in the most meaningful way, which will accurately describe every case.

A considerable amount of research has been done and reported concerning the measurement and evaluation of undyed and dye-whitened paper in terms of the general method of measuring color (*1*). An analogous study of evaluation of papers treated with optical bleaches was recently published (*4*). In this later work, it was reported that the whitening effects are directly proportional to effective fluorescence, defined as the sum of the CIE tristimulus values of the fluorescent light from the dye. In such a case the effective fluorescence (tristimulus sum) is claimed to be a reliable indication of the whitening power.

The objectives here have been to show how the complete radiation can be reliably measured and to find a simple means for expressing the measured results. If we were concerned with paper made from only one pulp and if the same brightening agent were used for all samples, the peak emittance would provide a precise evaluation of the action of the brightening agent. However, if different pulps and different brightening agents are involved, then one parameter, such as the peak emittance, is probably not sufficient. Attempts were made to determine another parameter which, together with the wavelength of peak emittance, would specify the particular sample satisfactorily.

Integration with $\bar{z}$ Function

Since all brightening agents act in the spectral range between 400 and 500 mμ, the complete radiation curves obtained in the measurement described earlier were integrated using the CIE $\bar{z}$ function, by the method of 10 selected ordinates. Value of the $\bar{z}$ function for nine samples integrated in this fashion are shown in Table I. The results are questionable in some cases because the integration does not put enough weight on the region close to 400 mμ. This is the difficulty with CIE color-mixture functions, namely, that they do not sufficiently weight the violet and blue region of the spectrum, and in the problem of fluorescence this is the region in which the large portion of fluorescent energy occurs.

Since the specification of complete visible radiation by the $\bar{z}$ function is questionable, attempts were made to introduce another parameter for expressing the complete radiation data. This parameter is derived from a statistical analysis by the method of principal components (characteristic vectors). Although principal-components analysis and vector algebra may seem rather complex for this purpose, once the vectors are derived, the usage is quite simple. All that needs to be done is to obtain for a few selected wavelengths the sum of the product of the recorded radiation values and the weighting function, W_1 (given in Table II), and to subtract from that the number 2.6494 (also given in Table II), which is the sum of the products of the reference radiation curve and the weighting function W_1. Thus, with this simple procedure, a parameter, Y_1, is obtained which can be used to specify the complete radiation. The advantage of using the Y_1 vector specification is that this vector describes directly the contribution of the fluorescence radiation to complete radiation and does not depend on any particular illuminant. A brief

Table I. Comparative Results

1 Sample no.	2 Fig. no.	3 Maximum total radiation	4 λ at maximum of column 3 in mμ	5 Y_1	6 z_1[a]	7 z_2[a]
1	8	85.5	435	0	102.7	102.5
2		85.7	435	0.098	103.1	102.8
3		89.1	437	0.790	103.5	103.6
4		95.0	434	1.594	109.9	109.7
5		96.0	440	1.629	110.7	110.3
6	8	96.1	437	1.678	110.4	110.2
7	8	97.5	437	1.983	111.2	110.9
8		100.2	435	2.099	113.2	113.4
9	6	103.5	404	2.412	114.4	114.5

[a] Tristimulus values and chromaticity coordinates of an equal energy spectrum for 10°—field observation, derived in accord with a decision of CIE working committee W-1.3.3 on colorimetry from data obtained by Stiles and Burch at the National Physical Laboratory.

discussion of the basis for Y_1 is given in the next section.

CHARACTERISTIC VECTORS

It was found by the method of principal components (*5*) that the variations among the data representing a wide variety of samples treated with different optical bleaches in various amounts could be expressed adequately as linear combinations of two basic radiation functions, i.e., the first two characteristic vectors derived from the variance-covariance matrix of the radiation data from the samples tested. This means that the radiation differences (at each wavelength) between a sample and a reference radiation curve can be given by:

$$B_{\lambda i} - R_{\lambda i} \cong Y_1 V_{1,\lambda i} + Y_2 V_{2,\lambda i} \qquad (1)$$

where B_λ is the sample radiation data at λ, and R_λ is the reference radiation data at the same wavelength. The characteristic vectors, V_1 and V_2, are invariant for all samples belonging to the original set from which the vectors were derived. The values of Y_1 and Y_2 vary from sample to sample, and, together with the reference data R_λ, constitute a full specification of the complete radiation of each sample.

The values of Y_1 and Y_2 are determined as simple linear combinations of radiation data at selected wavelengths.

The vectors derived in the study of a wide variety of samples treated with different optical bleaches were based on radiation data obtained at the wavelength of maximum radiation and at four selected wavelengths below, and nine selected wavelengths above the wavelength of maximum radiation. Table II lists the elements of V_1 at each of the 14 wavelengths. The wavelength spacing between the selected wavelengths is indicated. Also listed are the values of the weighting coefficients, W_i, in the equation,

$$Y_1 = \text{constant} + W_{\lambda_1} r_{\lambda_1} + W_{\lambda_2} r_{\lambda_2} + \ldots W_{\lambda_{14}} r_{\lambda_{14}} \qquad (2)$$

where $r_{\lambda i}$ represents the radiation data for any sample. The constant term is dependent upon the choice of reference radiation data. If the reference radiation data are those given in column 5 of Table II, the constant term in the equation (2) is −2.6494. The values of $V_{1,\ i}$ and W_i are plotted in Fig. 11. Figure 12 shows the reference curve and the combinations:

(a) $R_\lambda + 0.2V_1$; (b) $R_\lambda + 0.5V_1$; (c) $R_\lambda + 1.0V_1$

(d) $R_\lambda + 1.5V_1$; (e) $R_\lambda + 2.0V_1$; and (f) $R_\lambda + 3.0V_1$.

The effect of adding vector V_1 to the reference radiation vector is basically the contribution of the fluo-

Table II. Vector Elements

1 Choice of wavelength, mμ	2 Step	3 V_1	4 W_1	5 Ref λ
−10	1	−16.18383	−0.03678	80.52
−10	2	−5.53492	−0.01258	83.05
−10	3	+3.06543	+0.00697	84.09
−5	4	5.97212	0.01357	84.95
Peak wavelength	5	6.07832	0.01381	85.35
+5	6	5.60218	0.01273	85.77
10	7	4.13838	0.00940	86.73
10	8	2.89019	0.00657	87.54
10	9	2.13745	0.00486	88.11
10	10	1.45662	0.00331	88.64
10	11	0.96934	0.00220	89.11
10	12	0.73120	0.00166	89.44
10	13	0.53989	0.00123	89.78
	14	0.38612	0.00088	90.13

Σ Ref $\times$ W_i = 2.6494

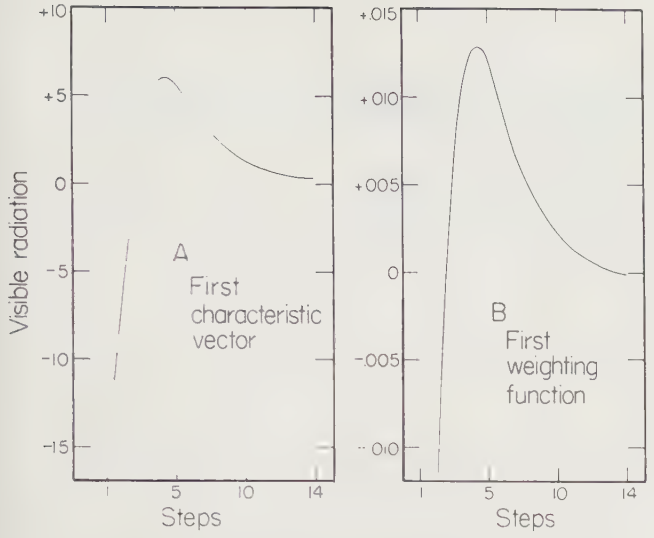

Fig. 11. Visible radiation: A, first characteristic vector; B, first weighting function

rescence.* This is exactly what we are trying to determine. The second vector, V_2, represents the nonfluorescent reflectance changes among various samples. The reflectance of a sample depends to some degree on the purity of the pulp used. These two characteristic vectors represent the characteristic ways in which such samples vary. These two vectors together account for approximately 95% of the original radiation data variability. Since only two vectors, together with the reference vector, are necessary for reasonably accurate reconstruction of the original data, a complete description of the shape of all complete radiation curves likely to be encountered in practice is given by the values of Y_1 and Y_2, the amounts of the vectors which must be added to the reference curve in order to reconstitute the original data.

Since vector V_1 represents the variation in which we are interested, namely, the fluorescence contribution to the brightness of a sample, it is sufficient and valid to specify the brightness with this parameter, together with the maximum value of complete radiation and the associated wavelength as shown by the recorded curve.† Therefore, the brightness of the sample is completely specified by:

1. The maximum value on the curve at the wavelength of peak emittance and the associated wavelength.
2. The parameter, Y_1, which is determined for every complete radiation curve separately by equation (2).

An example of calculation and comparison among various samples with various brightening agents and various concentrations of brightening agents is shown in Table I. Column 1 identifies the sample number; column 2 indicates the figure in which the sample curve is plotted; column 3 is the maximum value of complete visible radiation taken from curves recorded by the Beckman DK-2 spectrophotometer with a reversed optical system; column 4 shows the wavelength at

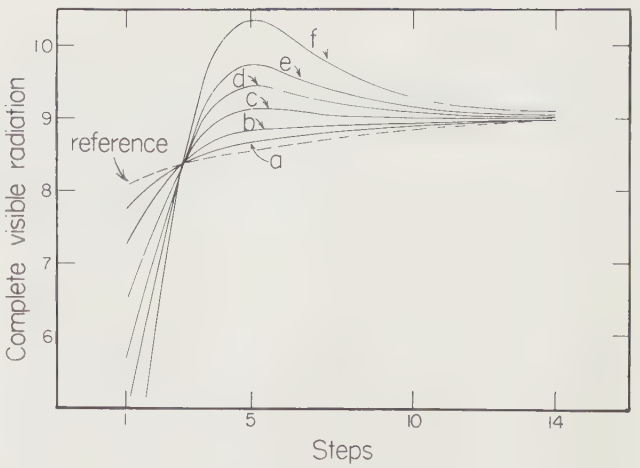

Fig. 12. Visible radiation of the reference vector and the combinations: (a) $R\gamma + 0.2\ V_1$, (b) $R\gamma + 0.5\ V_1$, (c) $R\gamma + 1.0\ V_1$, (d) $R\gamma + 1.5\ V_1$, (e) $R\gamma + 2.0\ V_1$, (f) $R\gamma + 3.0\ V_1$

which the maximum value occurs; and column 5 is the parameter, Y_1, which is now used to specify fluorescent brightening. Column 6 shows the results of the integration with the $\bar{z}$ function of the CIE system ($\bar{z}$ function of 1931 standard observer), combined with illuminant C, and column 7 shows the results of similar integration with a tentatively revised $\bar{z}$ function.*

Table I is arranged so that sample 1 represents the case where no optical bleach was used. The rest of the values in Table I, obtained from the samples treated with various optical bleaches and various concentrations, are arranged in order of increasing brightness as evaluated by observation. It can be seen from Table I that the value of Y_1 increases monotonically with increasing observed brightness of sample and is zero for the sample in which no optical bleach was used.

The integration with the $\bar{z}$ function does not agree in all cases with the visual determinations and does not indicate when the sample was not treated with an optical bleach. Therefore, the usage of the parameter Y_1 is recommended as a second parameter to specify the brightness of the samples treated with optical bleaches.

CONCLUSION

It is shown that the Beckman DK-2 spectroreflectometer, when its optical path is reversed and an appropriate light source provided, can be efficiently used to measure accurately the complete visible radiation of materials to which brightening agents are added.

The brightness of a sample can be specified by the maximum emittance value and the wavelength at that value, together with the parameter Y_1.

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* The parameter Y_1 is derived as a purely statistical parametric representation of the differences among a family of response vectors. The fact that V_1 is directly interpretable as the radiation contribution due to fluorescence is not a requirement of the mathematical analysis.

† The vector, V_1, has been derived from a family of practical radiation curves. It can be assumed to apply only to radiation data of the same basic type as was used in the principal-components analysis. For the specification of radically different radiation data, a new vector system may be required.

* See *a* in Table I.

Received Sept. 9, 1959. Presented at the 10th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Portland, Ore., Aug. 17–21, 1959.

The writers are indebted to J. L. Tupper and to D. L. MacAdam for valuable advice, and to John M. Patek and Robert L. Henley for initiating the problem and for extensive correspondence.

The Methanol-Extractable Aromatic Materials in the Inner Bark of *P. tremuloides*

HORACE B. FABER, JR.

Ten aromatic compounds have been identified in the methanol extracts of aspen inner phloem and stone cell layer. Pyrocatechol, benzoic acid, vanillic acid, *p*-hydroxybenzoic acid, and *p*-coumaric acid have been isolated as crystalline materials. A crystalline compound, tentatively identified as salireposide, has also been isolated. Paper chromatography of the various extracts also revealed the presence of salicin, populin, tremuloidin, and ferulic acid. In addition, data concerning the seasonal variation of materials present in these extracts were obtained. In the light of the newer views of lignin formation, it appears that the cambial activity and the formation of methoxyl groups are closely associated.

DURING the past decade, considerable attention has been focused on the biosynthesis of lignin. Klason's hypothesis (*1*, *2*) that coniferyl alcohol, stored as the glucoside coniferin, is the basic unit of gymnosperm lignin has had wide acceptance and has been fortified over the years by the weight of experimental evidence. Freudenberg (*3*) has extended these early concepts to the building stones for angiosperm lignins. In trees, the glucosides, coniferin and syringin, are thought to be synthesized outside the zone of lignification and transported to the sites of lignification via the inner bark. Erdtman (*4*) has postulated that coniferyl alcohol would react in accord with the reaction mechanism whereby isoeugenol is converted into dehydrodiisoeugenol. Freudenberg (*5–7*) has extended this idea to include enzymatic coupling and polymerization of the lignin building stones.

Particularly as a result of information obtained in the past decade, the newer views concerning the biochemistry of lignin have resulted in a general concept which traces the biosynthesis of lignin from its origin to its final deposition in the cell wall. A condensed version of the general biosynthetic pathway to lignin appears in Fig. 1.

In a recent study of newly formed aspenwood, Mugg (*8*) found several low-molecular weight phenolic materials which could be considered structurally to be precursors of lignin. However, no comparable investigation of aspen inner phloem has been made.

In xylem, the lignification of fibers is a prominent feature. The inner phloem has fewer lignified fibers, but is important in the transport and storage functions of the tree. It might be expected that certain of the lignin precursors would be more readily detectable if present as reserve matter in this tissue. Thus, this study was concerned primarily with the occurrence of low-molecular weight phenolic materials in the inner phloem of aspen. In addition, the phenolic composition of the stone cell layer and seasonal variations[a] were also studied.

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GLOSSARY

1. Inner Phloem—that portion of phloem tissue which lies between the cambium and the last-formed stone cells.
2. Stone Cell Layer—that portion of phloem tissue which lies between the inner phloem and periderm layer.
3. Whole Inner Bark—a combination of inner phloem and stone cell layer.
4. Whole Bark—all tissue lying outside the cambial layer.
5. Soft Xylem—newly formed tissue containing 5 to 10% lignin.
6. T-74, 75—a composite sample from tree T-74 and tree T-75.
7. Paper Chromatographic Developers:
   (*a*) Toluene–acetic acid–water (4:1:5)–TAW (*11*).
   (*b*) *n*-Butanol–acetic acid–water (4:1:5)–BAW (*10*).
   (*c*) *n*-Butanol saturated with 2% aqueous ammonia–BAm (*23*).
   (*d*) *n*-Butanol–pyridine–water (10:3:3)–BPW (*17*).
   (*e*) Phenol–formic acid–water (3:0.01:1)–PFW (*21*).
   (*f*) Benzene–acetic acid–water (2:2:1)–BzAW (*24*).
   (*g*) *n*-Butanol saturated with aqueous 1.5 *N* ammonia and ammonium carbonate–BAmC (*25*).
   (*h*) *n*-Butanol–ethanol–1.5 *N* ammonia, 1.5 *N* ammonium carbonate (40:11:19)–BEAmC (*25*).
8. Spray Reagents:
   (*a*) 2,4-Dinitrophenylhydrazine–DNPH (*12*).
   (*b*) Alcoholic ferric chloride–FC (*13*).
   (*c*) Diazotized *p*-nitroaniline–PNA (*14*).
   (*d*) Mäule test reagent (*15*).[a]
   (*e*) Wiesner test reagent (*16*).[b]
   (*f*) *p*-Anisidine–pA (*18*).
   (*g*) Sodium metaperiodate–piperazine–sodium nitroprusside–PPN (*22*).
   (*h*) Silver nitrate–SN (*19*).

[a] Mäule test procedure—The dried chromatograms were moistened with steam and placed in an atmosphere of chlorine for 10 min. and then sprayed with a freshly prepared 10% solution of sodium sulfite. A positive test is a cerise coloration.

[b] Wiesner test reagent—1% phloroglucinol in 12% hydrochloric acid.

EXPERIMENTAL

All experimental work was performed on the inner phloem and stone cell layer of *Populus tremuloides* trees cut from the Rhinelander Paper Co. Industrial Forest, Eagle River, Wis. Tissue samples were collected at four intervals throughout a one-year growing cycle: October, 1957, trees T-74 and T-75; February, 1958, T-76 and T-77; May, T-81 and T-82; and July, 1958, T-88, 89 and 90. After the trees were felled and the branches removed, the stem was cut into short bolts. The techniques used to secure the two layers of bark tissue were as follows:

Stone Cell Layer. The outer bark was scraped from the bolts with a potato peeler. The orange-brown tissue exposed was the stone cell layer. This layer was removed with a spokeshave and placed in methanol. Since the inner phloem lay just inside this tissue, care was taken to avoid inclusion of inner phloem in the stone cell layer.

Inner Phloem. The bolt with part of the stone cell layer removed was then cleaned of residual stone cell

[a] It should be noted that tissue samples from enough trees were not obtained to draw any statistically valid conclusions regarding seasonal variation.

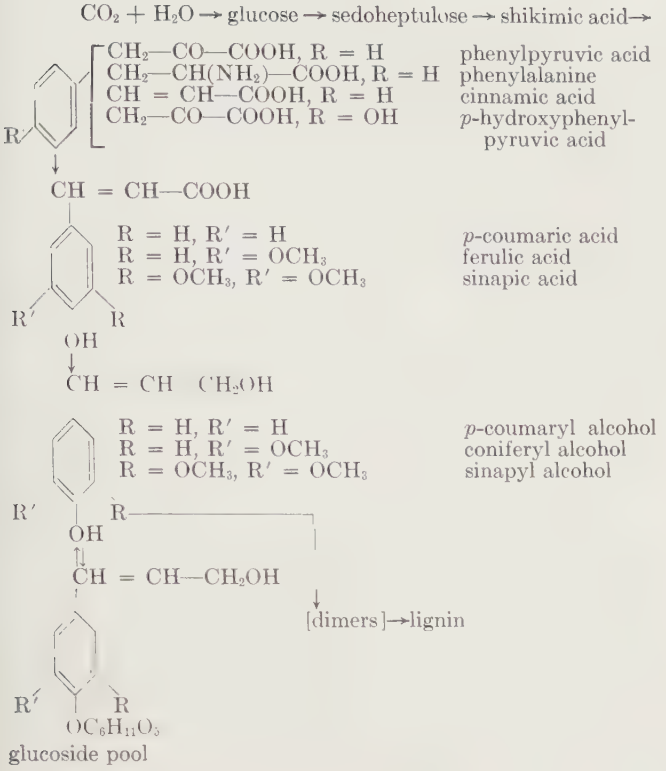


Fig. 1. The general biosynthetic pathway to lignification

tissue with a jackknife. The tissue exposed was the cream-colored, fibrous inner phloem. The jackknife was placed nearly parallel to the surface of the bolt and drawn lengthwise along its surface. The inner phloem separated from the wood very easily and could always be differentiated from xylem in case of a deep cut by the difference in texture and color, the xylem being lighter in color and more dense than the inner phloem.

Extraction Procedures

All extractions were performed at room temperature. The methanol used at the time of collection was decanted after four days and fresh methanol added. Two additional solvent changes were made with a total extraction time being 12 to 14 days.

Fractionation Procedures

The methanol extracts were fractionated according to the schemes of Mugg (*8*) and Sultze (*9*). The extracts were first concentrated under vacuum to a water solution. During this operation, a dark brown resinous material separated. The water was decanted and this precipitate washed and redissolved in methanol. The water solution was then exhaustively extracted with hexane followed by ether. After concentration, the ether solutions also yielded small deposits of a gummy material similar in color to the precipitates-from-water. The ether was decanted and these precipitates redissolved in methanol.

Tables I and II report the yields obtained in the various fractions.

Differences Between Trees

The various fractions of T-74 and T-75 inner phloem and stone cell layer were compared by paper chromatography using *n*-butanol–acetic acid–water (4:1:5) (*10*) and toluene–acetic acid–water (4:1:5) (*11*). The locations of the spots were determined by visual and

Table I. Yields of Materials Extracted from Inner Phloem

Fraction	*Season*			
	Fall	*Winter*	*Spring*	*Summer*
Total methanol extractives, %[a]	10.4	22.8	20.7	32.0
Precipitate-from-water, %[a]	1.5	3.8	3.1	5.4
Hexane-soluble materials, %[a]	2.7	3.6	2.2	5.3
Ether-soluble materials, %[a]	0.4	0.8	1.8	1.5
Water-soluble materials, %[a]	5.8	14.6	14.2	19.9

[a] Calculated on basis of airdry, extracted tissue.

ultraviolet examination (UV) and by spraying with 2,4-dinitrophenylhydrazine (DNPH) (*12*), alcoholic $FeCl_3$ (FC) (*13*), diazotized *p*-nitroaniline (PNA) (*14*), and by use of the Mäule (*15*) and Wiesner (*16*) test reagents.

The two extracts representing the inner phloem were quite similar as were the two extracts from the stone cell layer. However, the water-soluble materials and the precipitates-from-water from the stone cell layers contained more materials than the corresponding fractions of inner phloem. The slight differences between the extracts from the two trees did not warrant separate treatment, and in all ensuing sample collections, two extracts were obtained, a composite of inner phloem tissue and a composite of the stone cell layers from the same trees.

THE WATER-SOLUBLE MATERIALS

Paper Chromatography

Paper chromatography of these fractions was performed with BAW and *n*-butanol–pyridine–water (BPW) (*17*). The papers were sprayed with *p*-anisidine HCl (pA) (*18*), $AgNO_3$ (SN) (*19*), PNA and the Mäule and Wiesner test reagents. R_f values and color reactions with pA, SN, and PNA appear in Table III. Mäule-positive materials were detected in all water-soluble fractions. However, these materials streaked from $R_f = 0.50$ to 0.75 and $R_f = 0.45$ to 0.80 with BAW and BPW, respectively. Weisner-positive materials were not found in T-74, 75 or T-88, 89, 90 inner phloem and T-88, 89, 90 stone cell layer. All other water-soluble fractions contained Wiesner-positive materials which also streaked with BAW and BPW.

Table IV summarizes paper chromatographic data of authentic compounds which were determined in conjunction with the data appearing in Table III.

On the basis of this evidence, all of the water-soluble fractions of inner phloem and stone cell layer contain the following compounds: Compound A, sucrose; Compound B, glucose; Compound C, fructose; Com-

Table II. Yields of Materials Extracted from the Stone Cell Layer

Fraction	*Season*			
	Fall	*Winter*	*Spring*	*Summer*
Total methanol extractives, %[a]	10.6	15.3	11.4	18.7
Precipitate-from-water, %[a]	2.6	4.5	4.3	8.1
Hexane-soluble materials, %[a]	1.4	1.5	1.2	2.1
Ether-soluble materials, %[a]	0.3	1.4	0.2	1.5
Water-soluble materials, %[a]	6.4	7.8	5.9	7.0

[a] Calculated on basis of airdry, extracted tissue.

Table III. R_f Values and Color Reactions of Compounds Found in All Water-Soluble Fractions of Inner Phloem and Stone Cell Layer

Spray R_f	0.08A[a]	0.14B	0.19C	Developer: BAW 0.56D	0.67E	0.80F	0.84G
pA	+ (brown)	+ (brown)	+ (yellow)	−	−	−	−
PNA	−	−	−	−	+ (purple)	−	−
SN	+	+	+	+	+	+	+
Spray R_f	**0.08A**	**0.13B**	**0.18C**	**Developer: BPW 0.55D**	**0.60E**	**0.74F**	**0.81G**
pA	+ (brown)	+ (brown)	+ (yellow)	−	−	−	−
PNA	−	−	−	−	+ (purple)	−	−
SN	+	+	+	+	+	+	+

[a] A, B, C, etc., refer to the compounds present in these fractions.

pound D, salicin; Compound F, populin; and Compound G, tremuloidin. There was no evidence for the presence of coniferin or syringin.

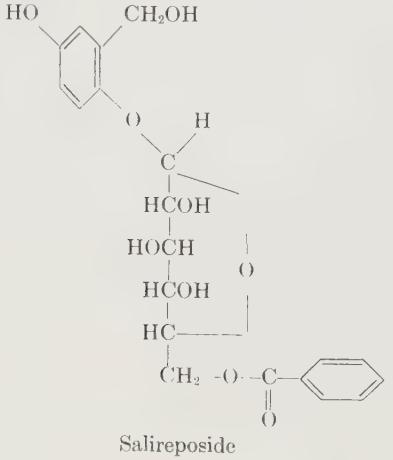
Isolation and Tentative Identification of Compound E

The water-soluble materials of T-81, 82 inner phloem had been set aside under refrigeration when it was noticed that small white burrs had begun to precipitate. These crystals were filtered, washed with cold water and recrystallized twice from hot water, yielding long colorless needles melting at 203 to 204°C. with an intermediate phase change occurring at 152–153°C.

Table IV. R_f Values and Color Reaction of Authentic Compounds

Compound	Spray pA	Spray SN	Spray PNA	R_f (BAW)	R_f (BPW)
Sucrose	+ (brown)	+	−	0.08	0.08
Glucose	+ (brown)	+	−	0.14	0.13
Fructose	+ (yellow)	+	−	0.19	0.18
Salicin	−	+	−	0.56	0.55
Populin	−	+	−	0.80	0.74
Tremuloidin	−	+	−	0.84	0.81

Hydrolysis of this material with 1 *N* HCl at 100°C. for 30 min. yielded glucose (pA, SN) and two other unidentified spots (PNA). Infrared spectral analysis of the crystals yielded a curve that was identical in all respects with an infrared spectrum of a crystalline material recently isolated from the whole bark of aspen by Pearl (*20*), who has tentatively identified this compound as salireposide.



Salireposide

The Hydroaromatic Acids

The water-soluble fractions of inner phloem and stone cell layer were also examined for hydroaromatic acids using a mixture of phenol–formic acid–water (3:0.01:1) (PFW) (*21*). The spray reagent was periodate-piperazine-nitroprusside (PPN) (*22*). All of the water-soluble fractions gave negative results. A sample of authentic shikimic acid was found at $R_f = 0.60$, and a sample of authentic quinic acid was detected at $R_f = 0.50$.

THE ETHER-SOLUBLE MATERIALS

The ether-soluble materials were fractionated by successive extractions with 21% $NaHSO_3$, 8% $NaHCO_3$, and 2% NaOH. The materials remaining in the ether after these extractions were designated the ether neutrals. Acidification of the water solutions and re-extraction with ether yielded the bisulphite-soluble materials, the bicarbonate-soluble materials and the sodium hydroxide-soluble materials.

Paper Chromatography of the Bisulphite-Soluble Materials

The bisulphite-soluble materials were analyzed by

Table V. R_{py}[a] Values and Color Reactions of the Materials Present in the Bisulphite-Soluble Fractions of Inner Phloem and Stone Cell Layer

Spray R_{py}	0.78H[b]	Developer: BAm 1.00I	1.05J
FC	−	+ (blue)	+ (blue)
Mäule	−	−	−
Wiesner	−	−	−
PNA	+ (yellow-green)	+ (purple)	+ (green)
DNPH	+ (yellow)	−	+ (yellow)
UV	−	d	−
Spray R_{py}	**0.49-0.77**	**Developer: BzAW 1.00I**	**1.84J**
FC	−	+ (blue)	+ (blue)
Mäule	−	−	−
Wiesner	−	−	−
PNA	+ (yellow-green)	+ (purple)	+ (green)
DNPH	+ (yellow)	−	+ (yellow)
UV	−	d[c]	−

[a] R_{py}, Reference pyrocatechol.
[b] H, I, J, Refer to compounds present.
[c] d, Dark fluorescence.

paper chromatography using *n*-butanol–2% aqueous NH_3 (BAm) (*23*) and benzene–acetic acid–water (BzAW) (*24*). The papers were sprayed with DNPH, FC, PNA, the Mäule and Wiesner test reagents and examined under ultraviolet light. Table V summarizes the chromatographic data obtained for all of the bisulphite-soluble materials from the inner phloem and stone cell layer.

Separation of Compounds H, I, and J

Compound I gave a blue color with FC and a purple color with PNA and had the same color reactions and movement properties in BzAW and BAm as authentic pyrocatechol.

Whatman 3MM paper was prepared by washing (descending chromatography) with water for 24 hr., air drying, washing again with water for 24 hr. and air drying, and finally washing with 95% ethanol for 24 hr. Twenty papers were streaked with the bisulphite-soluble fractions of T-81, 82 and T-88, 89, 90 inner phloem and developed for 5 hr. with BzAW. It was discovered that with 3MM paper, Compounds H and I had overlapped. Therefore, the areas containing the mixture of compounds H and I and Compound J were separately eluted with 95% ethanol.

The solution containing Compounds H and I was concentrated under vacuum to dryness. Since Compound H was probably water insoluble, i.e., a ketone or aldehyde, water-soluble pyrocatechol was separated from Compound H by adding 30 ml. water to the residue and allowing the mixture to stand for several hours with intermittent stirring. The undissolved solids were filtered and redissolved in 95% ethanol. This solution contained Compound H and was FC-negative. The filtrate contained pyrocatechol and was FC-positive.

Isolation and Characterization of Compound H

The solution containing Compound H was concentrated under vacuum to dryness and the residue dissolved in 100 ml. ether. This ether solution was concentrated until cloudy and placed in a refrigerator for several days. The solution yielded colorless spheres melting at 192 to 193°C.

The ultraviolet spectrum of Compound H revealed a minimum at 256 μ and a maximum at 273 μ with no alkaline shift. The infrared spectrum, shown in Fig. 2, suggested the possibility of two carbonyl groups.

A few crystals were hydrolyzed with 1 *N* HCl at 100°C. for 30 min. Chromatography of the hydrolyzate gave evidence for glucose and three other unidentified spots (SN). Compound H, therefore, appeared to be a glucoside.

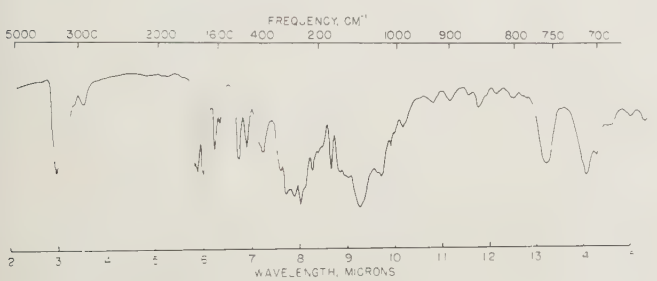
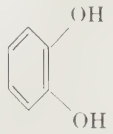


Fig. 2. Infrared spectrum of compound H

Isolation and Identification of Pyrocatechol

The solution containing Compound I, pyrocatechol, was concentrated under vacuum, to dryness. The residue was dissolved in 2 ml. benzene, filtered through cotton and the filtrate concentrated to 1 ml. On cooling, the solution yielded slightly yellow needles which melted at 102–104°C. and did not depress a mixed melting point with authentic pyrocatechol.



Pyrocatechol

Compound J

The solution containing Compound J was concentrated under vacuum to dryness and the residue dissolved in 15 ml. hot water. On cooling, the solution yielded a brown amorphous floc, which was concentrated by centrifugation, and washed twice with water. Because of the brown color and the fact that it tested positive to FC, decomposition was suspected. Actually, the major portion remained as a resinous mass even after warming with 95% ethanol.

Isolation and Identification of Benzoic Acid

During the fractionation involving bisulphite, the step requiring acidification of the water solution always resulted in a precipitate. This precipitate was subsequently dissolved in ether and carried along with the general chromatographic analyses. However, in the case of T-76, 77 inner phloem, the precipitate was allowed to settle, the water solution decanted and the residue dissolved in 95% ethanol.

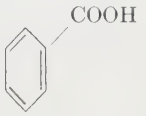
This solution was evaporated to dryness and set aside. After several months, extremely long, colorless needles were found growing from the walls of the flask by sublimation.

Table VI. R_{va} Values and Color Reactions of the Materials Present in the Bicarbonate-Soluble Fractions of Inner Phloem and Stone Cell Layer

Spray R_{va}[a]	*Developer: BzAW*			
	*0.62*K[b]	*0.65*L	*1.00*M	*1.03*N
FC	–	+ (orange)	–	–
Mäule	–	–	–	–
PNA	+ (red)	+ (blue)	+ (purple)	+ (gray)
UV	d[c]	d	–	l[d]
Spray R_{va}	*Developer: BAmC*[e]			
	*1.00*M	*1.23*K	*1.63*L	
FC	–	–	+ (orange)	
Mäule	–	–	–	
PNA	+ (purple)	+ (red)	+ (blue)	
UV	–	d	d	
Spray R_{va}	*Developer: BEAmC*			
	*1.00*M	*1.25*K	*1.32*N	*1.67*L
FC	–	–	–	+ (orange)
Mäule	–	–	–	–
PNA	+ (purple)	+ (red)	+ (gray)	+ (blue)
UV	–	d	l	d

[a] Reference vanillic acid.
[b] K, L, M, and N refer to materials present.
[c] d, Dark fluorescence.
[d] l, Light fluorescence.
[e] Compound N not determined using this developer.

The infrared spectrum of these crystals was identical with a spectrum of authentic benzoic acid except for minor bands at 1249 cm.$^{-1}$ and 767 cm.$^{-1}$. A few crystals were placed in a capillary tube and resublimed. The melting point of the resublimed crystals was 119 to 120°C. When mixed with an authentic sample of benzoic acid, the melting point was depressed one degree to 120 to 121°C.



Benzoic Acid

Paper Chromatography of the Bicarbonate-Soluble Materials

The bicarbonate-soluble materials were analyzed by paper chromatography with BzAW–*n*-butanol saturated with a buffer solution of 1.5 *N* NH_3 and $(NH_4)_2CO_3$(BAmC) (*25*), and the upper phase of a mixture of *n*-butanol–ethanol–1.5 *N* NH_3 and $(NH_4)_2CO_3$ (40:11:19) (BEAmC) (*25*). The papers were sprayed with PNA, FC, the Mäule test reagent and examined under ultraviolet light. Table VI summarizes the data obtained for all of the bicarbonate-soluble materials from the inner phloem and stone cell layer.

Paper chromatography of authentic samples with the above developers revealed that the bicarbonate-soluble fractions contained: Compound K, *p*-hydroxybenzoic acid; Compound L, *p*-coumaric acid; Compound M, vanillic acid; and Compound N, ferulic acid. These compounds were present in all of the bicarbonate-soluble fractions with the following exceptions: ferulic acid was absent in T-74, 75 inner phloem and stone cell layer; vanillic acid was present only in T-74 75 inner phloem and T-81, 82 stone cell layer.

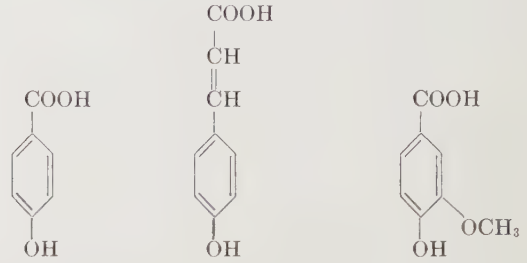
Separation of Compounds K, L, and M

Four sheets of Whatman 3MM paper were thoroughly washed with BzAW, and then spotted with the bicarbonate-soluble fraction of T-74, 75 inner phloem. The papers were developed in BzAW for 7 hr. Vanillic acid had been completely separated at R_f = 0.70 while *p*-hydroxybenzoic acid and *p*-coumaric acid overlapped at R_f = 0.43 and R_f = 0.45, respectively. The sections of the papers containing vanillic acid and the mixture of *p*-hydroxybenzoic acid and *p*-coumaric acid were eluted with 95% ethanol.

The solution containing the mixture of acids was concentrated to a few milliliters and spotted on four sheets of Whatman 3MM paper which had been previously washed with TAW. These papers were developed for 20 hr. with TAW. Complete separation of the two acids was accomplished, i.e., *p*-coumaric acid–$R_{\text{coumaric acid}}$ = 1.00; *p*-hydroxybenzoic acid–$R_{\text{coumaric acid}}$ = 0.64. The sections of the papers containing the two acids were eluted with 95% ethanol. The three alcoholic solutions were subsequently treated in the same manner.

Isolation and Identification of Vanillic Acid, p-Hydroxybenzoic Acid and p-Coumaric Acid

The alcoholic solution of each acid was concentrated to dryness and the residue extracted with ether. The ether solution was then decanted and evaporated to dryness. The residue was again extracted with ether, decanted and evaporated to dryness. This procedure was repeated two times. The ether-soluble solids were then dissolved in hot water, filtered through cotton and concentrated to dryness. This step was repeated two times. After the final filtration, the hot water solution was placed on a watch glass. The solutions containing Compounds K, L, and M, respectively, yielded: flat colorless platelets which melted at 212 to 214°C. and did not depress a mixed melting point with authentic *p*-hydroxybenzoic acid; long colorless needles which melted at 209 to 213°C. and did not depress a mixed melting point with authentic *p*-coumaric acid; and slightly yellow spheres which melted at 205 to 207°C. and did not depress a mixed melting point with authentic vanillic acid.



p-Hydroxybenzoic Acid | *p*-Coumaric Acid | Vanillic Acid

Paper Chromatography of the Sodium Hydroxide-Soluble Materials

The sodium hydroxide–soluble fractions of inner phloem and stone cell layer were chromatographed with BEAmC and found to contain ferulic acid, pyrocatechol, *p*-coumaric acid and at least three other unidentified materials which reacted with PNA but had very slow movement properties in the developing solvent used.

The Ether Neutrals

When these materials were chromatographed with TAW and BAW, no materials could be detected with FC, PNA, or the Mäule test reagent. Materials reacting with DNPH and the Wiesner test reagent were found near the solvent front as a streak, i.e., R_f = 0.85 to 0.95.

The Hexane-Soluble Materials

These materials were waxy and slightly yellow in color. They moved with the solvent front in TAW and gave the characteristic pink color with the Wiesner test reagent, which is probably due to oxidized fatty materials (*16*). Attempts to resolve these materials with BAW also resulted in considerable streaking. The Wiesner-positive materials and those detected in the ether neutral fractions were chromatographically similar.

The Precipitates-from-Water

The precipitates-from-water were dark brown viscous oils and were chromatographed with TAW and BAW. When using TAW, these materials moved quite slowly and always streaked from the origin. However, partial

resolution was accomplished with BAW. The chromatographic properties of the precipitates-from-water were reminiscent of similar materials isolated from the xylem (*8*). However, Mäule-positive materials were present only in the fractions from T-81, 82 and T-88, 89, 90.

The Precipitates-from-Ether

Paper chromatography with BAW and TAW revealed that these materials had movement characteristics similar to the precipitates-from-water, i.e., with BAW, the materials moved with the solvent front with streaking and with TAW, part of the materials streaked from the origin, but the major portion did not move.

THE MÄULE TEST ON THE METHANOL-EXTRACTED TISSUES

After the inner phloem and stone cell layer tissues had been extracted with methanol, they were allowed to air dry. A portion of each sample was subsequently soaked in water, chlorinated and finally treated with sodium sulphite. This Mäule test was positive for all of the samples collected and indicated the presence of the pyrogallol nucleus, especially the syringyl nucleus, in the methanol-insoluble lignin.

DISCUSSION

Ten aromatic compounds have been identified in this study. The fact that certain of these compounds are in harmony with biosynthetic pathways to lignin is not proof that they are lignin precursors. However, the absence of expected compounds and the presence of other aromatic materials may alter our ideas concerning the biological formation of lignin in the particular species *P. tremuloides*. What the presence of these compounds means will be examined primarily in the light of the newer views of lignin formation.

p-Coumaric Acid and Ferulic Acid

Para-coumaric acid and ferulic acid, two aromatic C_6-C_3 compounds considered to be precursors to coniferyl alcohol, were detected in the inner phloem of aspen. In addition, Pearl has shown that an alkaline hydrolysis of whole aspenwood yielded small amounts of *p*-coumaric acid but no ferulic acid (*26*). Beyer obtained the same results with a methanol extract of newly formed aspenwood (*27*). Thus, *p*-coumaric acid has been found in both the xylem and inner phloem of aspen, but ferulic acid has been detected only in the phloem tissue.

Xylem Lignin

If the Klason-Freudenberg hypothesis is valid, the presence of low-molecular weight syringyl derivatives would be expected in lignifying xylem tissues. And, indeed, Mugg found four ether-soluble, Mäule-positive materials in various lignifying aspenwood tissues (*8*). However, in the inner phloem, all of the ether-soluble materials extracted by methanol were Mäule-negative.

Angiosperm dicotyledonous lignin is thought to be composed primarily of guaiacyl and syringyl nuclei. If some of the aromatic materials present in the inner phloem do indeed move into the xylem, the questions arise: From where does the syringyl nucleus originate? Is it formed from the guaiacyl or the *p*-hydroxyphenyl nuclei found in the inner phloem? If *p*-coumaric acid and ferulic acid are considered lignin precursors, it appears that the cambium may affect in some manner the synthesis of compounds having the syringyl nucleus. Ferulic acid apparently is not a source of syringyl nuclei since Brown (*28*) suggests that the guaiacyl nucleus, once formed, probably does not undergo further methoxylation during lignification. Thus, the *p*-hydroxyphenyl nucleus of *p*-coumaric acid may be transformed into the syringyl nucleus, to some degree, during its transport through the cambium. If *p*-coumaric acid were undergoing methoxylation in the cambial zone, small quantities of the *p*-hydroxyphenyl nucleus could possibly be incorporated into the lignin. This event would probably explain the detection of this acid by an alkaline hydrolysis of aspen.

On the other hand, the absence of ferulic acid in the methanol extracts of Mugg (*8*) and in Beyer's (*27*) alkaline hydrolyzates of the methanol extracts of aspenwood is paradoxical. If ferulic acid and *p*-coumaric acid are lignin precursors, the absence of ferulic acid in xylem suggests either (1) this acid may be completely incorporated into the lignin so that none is available for extraction or hydrolysis, or (2) ferulic acid may be altered when transported from the phloem into the xylem.

Phloem Lignin

This study revealed that low-molecular weight, ether-soluble extractives of inner phloem and stone cell layer were Mäule-negative. Conversely, the methanol-extracted inner phloem and stone cell layer tissues which contain high-molecular weight materials, i.e., methanol-insoluble, were Mäule-positive. If some of the aromatic materials of these tissues serve as phloem lignin precursors, the question again arises: Where does the syringyl nucleus, present in the high-molecular weight materials of phloem, originate? If *p*-coumaric acid and ferulic acid are considered precursors to phloem lignin, the pathways leading to the formation of syringyl nuclei in the phloem from either of these acids are apparently not parallel to the pathways mentioned above for the formation of syringyl nuclei in xylem. The possibility of a direct polymerization of these acids, or their corresponding alcohols, followed by some hydroxylation and/or methoxylation would be in harmony with the above evidence. However, Adler (*28*) has commented concerning the possibility of rather specific reactions occurring in a preformed polymer: "... that such enzymatic transformations in a preformed high-molecular material of the type of lignin appear to have little probability."

The Precipitates-from-Water

The phloem precipitates-from-water are dark brown viscous oils whose chromatographic behaviors are reminiscent of Mugg's xylem isolated aspen lignin (*8*). Since these precipitates are methanol-soluble and water-insoluble, they probably contain some higher molecular weight materials. It should be noted that these precipitates were Mäule-negative when the cambium was dormant, but were Mäule-positive during the spring and summer months. It appeared that

hydroxylation and/or methoxylation in the bark tissues occurred when the cambium was active.

The Glucosides—Salicin, Populin, Tremuloidin, Salireposide

The current views of lignin formation postulate the presence of the glucosides coniferin and syringin in angiosperm dicotyledons. However [Kremers (*29*)], the actual isolation or detection of these glucosides is limited to comparatively few species of woody plants, and they have not been detected in this study. But the evidence presented in this study and by Pearl (*20*) reveals the presence of four other glucosides in aspen inner bark, salicin, populin, tremuloidin and salireposide.

If glucoside-hydrolyzing enzymes are present in the cambial sap of aspen, as has been shown by Freudenberg (*3*) in the case of spruce, these saligenin glucosides might be hydrolyzed if they move into and through the cambial zone. Recently, Reeder (*30*) has isolated salicin from the soft xylem of aspen, suggesting some inward radial movement. However, the aromatic C_6-C_1 unit with the *o*-hydroxyl substitution has not been found in mature xylem.

It is interesting to note that saligenin is the first reaction product of the well-known phenol-formaldehyde condensation reaction. Van Rijn (*31*) has reported that the reactions as well as the reactivities of saligenin, coniferyl alcohol and sinapyl alcohol are quite similar in dilute acid, all three compounds yielding amorphous resins. The similar reactivities of these alcohols would be expected since the only essential difference between coniferyl and sinapyl alcohols and saligenin is the presence of an allylic system. Thus, if glucoside-hydrolyzing enzymes are present in the cambial sap of aspen, one might expect the cleavage of the glucosides to yield the highly reactive alcohols which could polymerize.

p-Hydroxybenzoic Acid, Vanillic Acid, Benzoic Acid

The current views of lignin biosynthesis do not postulate the presence of either vanillic, benzoic or *p*-hydroxybenzoic acids. However, Davis (*32*) has shown that *p*-hydroxybenzoic acid is a necessary growth factor for several microorganisms which were employed in the studies of aromatic amino acid biosynthesis. Adler (*28*) suggested that the biosynthetic pathways leading to the synthesis of aromatic amino acids in these microorganisms may have general applicability to higher plants, and thus, this acid may be serving, in part, as a growth factor in *P. tremuloides*.

Extensive studies on hardwoods by Pearl (*33*) have shown that *p*-hydroxybenzoic acid was present in relatively large quantities only in the closely related *Populus* and *Salix* genera. However, Nakano (*34*) has found this acid in several gymnosperms, tropical hardwoods and other angiosperm dicotyledons. In the case of aspenwood, *p*-hydroxybenzoic acid has been reported not only as an extractive by Mugg (*8*), but also as part of the cell wall by Stanek (*17*), as a constituent of "isolated native aspen lignin" (*P. tremula*) by Smith (*35*), and associated with the Klason lignin of aspenwood by Busche (*36*). This acid was also shown to occur as an ester in aspenwood lignin by Nakano (*34*).

The presence of vanillic and *p*-hydroxybenzoic acids in the inner phloem of aspen could result from the oxidation of ferulic and *p*-coumaric acids, respectively. A possible relationship between *p*-coumaric and *p*-hydroxybenzoic acids was borne out to some extent by the alkaline hydrolyses of the water-soluble materials of the methanol extracts of whole inner bark, soft, and year-old xylem by Beyer (*27*). The concentrations of *p*-coumaric acid relative to *p*-hydroxybenzoic acid were noted to be: whole inner bark, 8/1; soft xylem, 5/1; and year-old xylem, 1/5.

The presence of benzoic acid in the inner phloem could theoretically be attributed to a mild hydrolysis of the glucosides populin, tremuloidin or salireposide. These glucosides could also account for the presence of *p*-hydroxybenzoic acid in aspenwood through a hydroxylation mechanism previously postulated to be influenced by the cambium.

Pyrocatechol

Pyrocatechol has been shown to occur in the roots and bark of numerous woody plants by von Lippmann (*37*), Kritchevsky, *et. al.* (*38*), and Plakhova, (*39*).

It should also be noted that several compounds have been isolated from fungal cultures by Ehrensvärd (*40*) which were not considered part of the direct pathway from glucose to shikimic acid but were thought to be accumulated as side products. These compounds were quinic acid, protocatechuic acid, and pyrocatechol. While the pathway discussed above has not been shown to exist in *P. tremuloides*, most of the evidence suggests that pyrocatechol is probably a metabolic end product in aspen bark.

SUMMARY AND CONCLUSIONS

Of the ten aromatic compounds detected in the methanol extracts of inner phloem and stone cell layer of aspen bark, *p*-coumaric acid, *p*-hydroxybenzoic acid, pyrocatechol, vanillic acid, and benzoic acid were positively identified; salicin, populin, tremuloidin, salireposide, and ferulic acid were tentatively identified.

Mugg's data (*8*) and the data of this study differed in that ether-soluble, Mäule-positive materials were present in lignifying xylem, but were absent in the inner bark of aspen.

In the case of the nine aspen barks studied, Mäule-positive materials found in the precipitates-from-water were present only during the growing season, suggesting a possible association between the formation of Mäule-positive materials and the activity of the cambium.

The presence of *p*-coumaric acid and ferulic acid in aspen inner bark is in harmony with the Klason-Freudenberg biosynthetic pathway to lignin formation and represents an earlier stage in this scheme than the sinapaldehyde identified by Mugg (*8*) from newly formed aspen xylem.

Coniferin and syringin were not detected in the methanol extracts of the inner bark of aspen.

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Received Oct. 26, 1959. A portion of a thesis submitted in partial fulfillment of the requirements of The Institute of Paper Chemistry for the degree of Doctor of Philosophy from Lawrence College, Appleton, Wis., June, 1959. This work was carried out under the direction of Roland E. Kremers.

Investigations of the Mannans and Xylans in Softwood

A. J. MORAK and KYLE WARD, JR.

A comparison was made of the efficacy of four alkaline extraction sequences in removing mannose and xylose units from holocelluloses produced from sprucewood and pulps. Under the conditions used, the following relations held. The most efficacious treatment was sodium hydroxide followed by potassium hydroxide for mannose and the reverse sequence for xylose. The use of alkaline potassium borate was good for xylose, with or without preliminary potassium hydroxide extraction, but the sequence potassium hydroxide followed by alkaline potassium borate removed only about half the mannose. An examination of the hemicellulose recovery showed interesting fractionation effects which are discussed and also the formation of a hemicellulose material soluble in 70% alcohol.

ALKALINE EXTRACTIONS OF SPRUCE HOLOCELLULOSES

THE complete removal of mannose from such softwood and softwood pulps as spruce is rather difficult. A similar condition exists with respect to xylans in hardwoods.

In this laboratory a comparison of the efficiency of sodium hydroxide and potassium hydroxide, both with and without the addition of borate, in removing mannose and xylose residues from holocelluloses of sprucewood and spruce pulps was recently made (*1*). It was shown that sodium hydroxide removed these materials from spruce sulfite pulps within the sensitivity of the method used (0.5%). This is in agreement with work recently reported on the purification of a spruce acetate pulp to a content of less than one part of mannan and xylan per thousand parts of glucan (*2*).

The present investigation is a comparison of the efficiency of the four following alkaline extraction treatments of sprucewood and pulps therefrom, namely: (I) sodium hydroxide followed by potassium hydroxide, (II) potassium hydroxide followed by sodium hydroxide, (III) potassium hydroxide followed by potassium borate, and (IV) potassium borate alone.

The same raw materials were used as in the previous investigations (*1*). They had been stored at slightly above room temperature (25–30°C.) for about one year since the first studies had been completed.

Descending paper chromatography was employed for the separation of the sugars of the hydrolyzates and the method of Timell and co-workers (*3*) was used for the quantitative determination of these sugars.

In the present work, the weights of the residues after each sequence of the alkaline treatments, as well as their sugar ratios, were determined. Similarly, the weights of the main portions of the hemicelluloses and their sugar ratios were determined. Uronic acids and rhamnose were not determined in the various hydrolyzates.

Experimental

Raw Materials. The materials used in these investigations are designated S_1, S_2, S_3, S_4, and S_5 and consisted of the following:

S_1 = sprucewood chips

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Table I. Preparation of Chlorite Holocellulose S_1–S_5

Sample	Chloriting, hr.	Used airdry purified material, g.	Chlorite holocellulose airdry obtained, g.	Yield, %
S_1	5	110	76	69.0
S_2	3	70	64.2	91.7
S_3	3	78	70	90.0
S_4	5	110	74	67.6
S_5	4	96	82	85.5

S_2 = unbleached sulfite pulp (from S_1)—cook I, permanganate no. 12.8
S_3 = unbleached sulfite pulp (from S_1)—cooks III and IV, permanganate no. 14.0
S_4 = sprucewood chips for kraft
S_5 = unbleached kraft (from S_4)

Samples were ground in the Wiley mill (mesh no. 4), then extracted in Soxhlet extractors with ethanol:benzene (1:2) mixture for 6 hr., followed by a 6-hr. extraction with 95% ethanol. Since grinding of samples in the previous work (*1*) was done under the very same conditions, it can be expected that a very similar state of mechanical cell disruption existed and penetrating conditions were equal in both investigations.

The airdried samples were chlorited according to the method of Wise (*4*). Three-hour chloriting appeared to be sufficient for the samples S_2 and S_3, whereas 4-hr. chloriting was required for sample S_5 and 5-hr. chloriting had to be employed for the samples S_1 and S_4. The residues of the latter two samples were of a slightly yellowish color. The yields of chlorite holocellulose are shown in Table I and the sugar ratios are tabulated in Table II.

Sugar Determination. The Forest Products Laboratory method of hydrolysis (*5*) was followed throughout this work. Three-hundred-milligram samples were hydrolyzed with 3.0 ml. of 72% H_2SO_4 for 1 hr. at 30° ± 0.1°C., then diluted with 84 ml. of distilled water and autoclaved (at 15-lb. pressure) for 1 hr. After cooling, the solutions were neutralized with a saturated barium hydroxide solution to pH 5.3 and the precipitate was removed by centrifuging and subsequent filtration of any peptized barium sulfate particles. Toluene was added to the clear filtrates in order to inhibit any microbiological destruction. Storage of the filtrates at 0°C. never exceeded a maximum period of 20 hr. Concentrating of the filtrates *in vacuo* was done to about 5 ml. and by rinsing of the flash evaporator with distilled water and ethanol, dilution to 10 ml. in volumetric flasks was made. These concentrates were streaked on Whatman no. 1 paper (that had very shortly before been washed twice for 24-hr. periods with distilled water with an intermediate drying period of approx. 8 hr.) usually the day following the hydrolysis. Sometimes samples had to be kept for a day or two in storage at 0°C. In these cases a few flakes of brownish color formed with the hydrolyzates of samples S_1 and S_4. All samples were run in duplicate and with each run known sugar solutions were spotted either on the sample chromatogram or separately. The following developing agents were used: ethyl acetate:acetic acid (99.8–99.9%):water (9:2:2) for approximately 28 to 30 hr., *n*-butanol:pyridine:water (10:3:3) for approximately 56 hr. and in thel atter part, ethyl acetate:pyridine:water (8:2:1) for about 34 hr. (*6*). None of the reagent-grade solvents was redistilled for these purposes. The spray reagent as well as the eluant were of 0.40% w/v concentration prepared by dissolving the purest obtainable (or recrystallized) *o*-aminodiphenyl in 75% glacial acetic acid (99.9%), mixing this solution with 16% distilled water and bringing up the volume with 9% glacial acetic acid. This solution was kept at 0°C. and never kept longer than 2 days. The developed chromatograms were airdried for at least 3–4 hr. until no solvents could be noticed, but never longer than one day. Spraying was done with approximately 25 ml. reagent for a $9^1/_4$ by 24-in. sheet. The sprayed chromatograms were dried for 3 to 4 min. at 100 to 105°C. and the individual sugar spots marked under ultraviolet light with pencil. These spots were cut out, along with two 6 by 4-cm. blanks, and the weight of each individual cut-out determined. Then these were cut into small pieces and put into 15-ml. Erlenmeyer flasks with ground-glass stoppers (g.g.s.).

Table II. Sugar Ratio in Chlorite Holocellulose
Samples S_1–S_5[a]

Sugar	S_1 Sprucewood for sulfite pulp	S_2 Sulfite pulp I cook	S_3 Sulfite pulp III & IV cook	S_4 Sprucewood for kraft	S_5 Kraft
Galactose	3.5	0.8	...	3.0	0.5
Glucose	68.8	86.0	88.7	75.9	85.2
Mannose	16.2	8.0	7.6	12.8	7.4
Arabinose	2.6	...	...	1.2	...
Xylose	8.9	5.2	3.7	7.1	6.9

[a] No correction made for destruction of sugars during hydrolysis.

The elution was made with freshly prepared 0.40% *o*-aminodiphenyl solution measured in early determinations from a buret, later by means of the automatic Matchlett pipet of ±0.01-ml. precision. The suspensions were shaken for over 30 min. on a shaker of 200 cycles per minute. The standard volume of eluant was 6 ml.; multiples were used whenever the sugar quantities were over 150 gammas; for over 400 gammas, 18- or 24-ml. eluant were usually used in vials with screw caps and polyethylene liners. Fine pulp particles were removed by filtration through microfilter tubes C or glass wool. Heating the elutriates was done first in 15-ml. g.g.s. Erlenmeyer flasks but later bacteriological tubes 160 mm. long were used, which were closed with screw caps having polyethylene liners. Both the pentoses and hexoses were heated in a boiling water bath for 45 min. to 100°C.; simultaneously, several portions of the reagent were heated, the boiled reagent serving as the reference solution. The colorimetric measurements were first made with the Beckman DU spectrophotometer; on account of the small quantity of elutriate, 1-ml. cuvettes often had to be used. Glucose determinations required a dilution with boiled reagent. Later on, a Coleman Universal spectrophotometer was used, and for small volumes, either a shielded carrier with spacers or a set of precision cuvettes 13 by 13 by

Table III. Yields of Residual Cellulose and Hemicellulose after Treatment I (NaOH-KOH)

S_1–S_5[a]

	S_1	S_2	S_3	S_4	S_5
Yield residual cellulose, %	54.85	79.88	74.78	55.28	78.25
Loss, total, %	45.15	20.12	25.22	44.72	21.75
Loss in 4 NaOH extns., %	43.97	19.32	19.99	40.53	20.68
Loss in 5 KOH extns., %	1.18	0.80	5.23	4.19	1.07
Hemicellulose recovered, %	34.41	14.53	12.94	39.63	16.38
Unaccounted for, %	10.74	5.59	12.28	5.09	5.37

[a] Figures are based on chlorite holocelluloses, *not* on original materials.

100 mm. with prisms, matched to $^1/_2$% transmission. Owing to the reduced light intensity by the deep purple filter PC-3 for the wavelength of 380 μ, a 12-v. battery with a rheostat was provided to secure a constant voltage of 8.0 v. at the required 4.3 amp. for the monochromator. At first, two developers had to be used in order to separate galactose from glucose and arabinose from mannose following the procedure of Piper and Bernardin (*7*). Later, the developer ethyl acetate:pyridine:water (8:2:1) permitted the separation of these sugars in a single step.

Table VI. Consistencies During Treatment I

S_1–S_5 expressed in % w/v[a]

Sequence of extn.	S_1	S_2	S_3	S_4	S_5
At start of 1st NaOH extn.[b]	1.00	0.95	1.07	1.04	1.07
At start of 1st KOH extn.[c]	2.42	1.23	2.30	1.58	2.26

[a] Weight of airdry chlorite holocellulose and residual cellulose, respectively.
[b] 3.4 *N* NaOH, i.e., 11.95% w/w or 135 g. NaOH (97.0% assay) per liter.
[c] 3.4 *N* KOH, i.e., 16.66% w/w or 193 g. KOH (85.0% assay) per liter.

NaOH, followed by one 24-hr. treatment in 16.8% KOH and four 24-hr. treatments in 10% KOH. After each extraction the residue was suctioned off, washed with 3% NaOH (or 5% KOH), washed with distilled water, neutralized with 10% CH_3COOH, washed free of acid, and dried with suction on the fritted glass filter and weighed. About 1-g. samples were drawn from each residue for the determination of moisture and the subsequent hydrolysis. Drying of these samples was done *in vacuo* at 28-in. Hg and 58°C. for 18 hr. or more. The filtrates from the first and second sodium hydroxide extractions were combined, acidified with acetic acid, and precipitated by pouring into the threefold quantity of 95% ethanol; after standing, the hemicelluloses were centrifuged, washed with 80, 90, and 95% ethanol, methyl alcohol and ether and then dried *in vacuo* like

Table IV. Sugar Ratios of Residual Celluloses—Treatment I (NaOH-KOH)

S_1–S_5[a]

	S_1			S_2			S_3			S_4			S_5		
Extracted	*Glucose*	*Mannose*	*Xylose*	*Glucose*	*Mannose*	*Xylose*	*Glucose*	*Mannose*	*Xylose*	*Glucose*	*Mannose*	*Xylose*	*Glucose*	*Mannose*	*Xylose*
1 time with NaOH	93.6	5.4	1.0	98.7	0.8	0.5	98.9	0.6	0.5	96.0	3.2	0.8	97.7	1.8	0.5
2 times with NaOH	97.1	2.5	0.4	98.9	0.7	0.4	99.3	0.5	0.2	96.3	3.0	0.7	98.6	1.1	0.3
3 times with NaOH	97.0	2.7	0.3	98.9	0.6	0.5	99.0	0.6	0.4	97.8	1.4	0.8	98.7	0.8	0.5
4 times with NaOH	96.8	2.6	0.6	98.8	0.8	0.4	99.2	0.5	0.3	97.9	1.8	0.3	98.5	1.2	0.3
1 time with KOH	96.6	2.7	0.7	98.8	0.8	0.4	99.1	0.7	0.2	98.1	1.6	0.3	98.4	1.2	0.4
2 times with KOH	97.3	2.1	0.6	98.8	0.8	0.4	98.9	0.8	0.3	97.7	1.9	0.4	97.8	1.6	0.6
3 times with KOH	98.1	1.6	0.3	98.9	0.8	0.3	...	...	...	98.2	1.6	0.2	98.9	0.8	0.3
4 times with KOH	97.9	1.8	0.3	99.0	0.7	0.3	99.0	0.7	0.3	98.2	1.5	0.3	99.1	0.7	0.2
5 times with KOH	98.5	1.3	0.2	99.5	0.3	0.2	99.8	0.3	0.1	98.5	1.3	0.2	99.3	0.5	0.2

[a] Sugars in their hydrolyzates expressed as the percentage of the total sugars found. Destruction of sugars during hydrolysis was not considered.

In extensive preliminary tests with various known sugar solutions only rarely were our checks as close as those of Timell (*3*). Irregular results differing by 30% or more were sometimes obtained on duplicate samples when analyzing the hydrolyzates. Such data were discarded and the determinations repeated to obtain valid results.

Extraction of the Chlorite Holocelluloses. All extractions were carried out under nitrogen at room temperature, using constant mechanical stirring. The concentrations of the alkaline extractants as well as the consistencies employed are shown in the respective tables. In general, extractions with sodium hydroxide were at approximately 1% consistency, with potassium hydroxide 2%, and with potassium borate 5%.

Treatment I: Sodium hydroxide–potassium hydroxide sequence: This consisted of one 24-hr. treatment in 12.0% NaOH, and three 24-hr. treatments in 7.1%

Table V. Sugar Ratios of Hemicellulose—Treatment I (NaOH-KOH)

S_1–S_5[a,b]

Sugar	S_1	S_2	S_3	S_4	S_5
Galactose	6.0	...	0.1	6.1	1.2
Glucose	18.4	44.9	41.2	17.3	36.3
Mannose	48.6	35.7	40.0	41.7	30.3
Arabinose	3.4	...	...	3.6	1.4
Xylose	23.6	19.4	18.7	31.3	30.8

[a] These hemicelluloses were recovered after the first and second sequence of NaOH extractions.
[b] No correction made for sugar destruction during hydrolysis.

the residues. Only turbidity was noticeable when the filtrate from the first potassium hydroxide extraction was added to alcohol.

Treatment II: Potassium hydroxide–sodium hydroxide sequence: This treatment is the reverse of treatment I. The hemicelluloses were isolated only from the first potassium hydroxide and the first sodium hydroxide extraction, and their sugar ratios determined.

Treatment III: Potassium hydroxide–potassium borate sequence: This treatment consists first of five potassium hydroxide extractions as described in treatment I, followed by two 2-hr. treatments and one 24-hr. treat-

Table VII. Yields of Residual Cellulose and Hemicellulose after Treatment II (KOH-NaOH)

S_1 S_5[a]

	S_1	S_2	S_3	S_4	S_5
Yield residual cellulose, %	52.98	73.84	77.48	51.16	74.05
Loss, total, %	47.02	26.16	22.52	48.84	25.95
Loss in 5 KOH extns., %	28.04	11.82	12.34	36.34	13.17
Loss in 4 NaOH extns., %	18.98	14.34	10.18	12.50	12.78
Hemicellulose recovered, %	28.06	10.85	12.35	28.92	13.14
Unaccounted for, %	18.96	15.31	10.17	19.92	12.81
Hemicellulose after 1st KOH, %	12.42	5.13	5.27	19.32	4.80
Hemicellulose after 1st NaOH, %	15.64	5.72	7.08	9.60	8.34

[a] Figures based on chlorite holocellulose, *not* on original materials.

Table VIII. Sugar Ratios of Residual Cellulose—Treatment II (KOH-NaOH)

S_1-S_5[a]

Extracted	S_1 Glucose	S_1 Mannose	S_1 Xylose	S_2 Glucose	S_2 Mannose	S_2 Xylose	S_3 Glucose	S_3 Mannose	S_3 Xylose	S_4 Glucose	S_4 Mannose	S_4 Xylose	S_5 Glucose	S_5 Mannose	S_5 Xylose
1 time with KOH	86.2	12.9	0.9	93.7	5.7	0.6	93.5	6.1	0.4	86.6	12.6	0.8	92.4	6.3	1.3
2 times with KOH	84.7	14.4	0.9	92.2	6.7	1.1	93.5	5.7	0.7	...	...	0.7	93.0	6.4	0.6
3 times with KOH	87.3	11.7	1.0	...	...	...	96.5	2.9	0.6	87.3	12.0	0.7	...	...	...
4 times with KOH	88.3	10.9	0.8	95.2	4.3	0.5	95.2	4.2	0.6	...	...	...	93.0	6.3	0.7
5 times with KOH	86.9	12.1	1.0	94.2	5.4	0.4	97.0	2.6	0.4	88.8	10.7	0.5	92.8	6.8	0.4
1 time with NaOH	94.7	4.8	0.5	99.0	0.7	0.3	98.5	0.9	0.6	97.1	2.6	0.3	97.9	1.5	0.6
2 times with NaOH	95.0	4.5	0.5	99.0	0.8	0.2	99.4	0.5	0.1	97.2	2.7	0.1	98.9	0.7	0.4
3 times with NaOH	95.1	4.6	0.3	98.9	0.8	0.3	99.1	0.6	0.3	97.5	2.3	0.2	99.1	0.7	0.2
4 times with NaOH	98.0	1.9	0.1	99.3	0.6	0.1	99.6	0.3	0.1	97.6	2.2	0.2	99.0	0.8	0.2

[a] Any galactose found was calculated as glucose and added to the glucose content. No correction made for destruction of sugars during hydrolysis.

ment with the alkaline potassium borate solution; the extractant consisted of 9 parts boric acid, 16.5 parts potassium hydroxide (14.4% water) and 74.5 parts water.

Hemicelluloses were isolated separately after the first potassium hydroxide extraction and after the first borate extraction; the hemicelluloses of the second and third borate extractions were combined.

Treatment IV: Potassium borate alone: This treatment consisted of three potassium borate extractions as described in Treatment III. Again only the residue of the third was washed, neutralized, washed again, and dried for weight determination. The hemicelluloses were isolated as in treatment III.

Table IX. Sugar Ratios of Hemicellulose—Treatment II (KOH-NaOH)

S_1-S_5[a]

Sugar	S_1 after 1st KOH	S_1 after 1st NaOH	S_2 after 1st KOH	S_2 after 1st NaOH	S_3 after 1st KOH	S_3 after 1st NaOH	S_4 after 1st KOH	S_4 after 1st NaOH	S_5 after 1st KOH	S_5 after 1st NaOH
Galactose	5.5	1.5	0.4	0.6	0.4	0.4	8.6	1.2	5.3	0.4
Glucose	23.9	16.6	18.7	47.1	19.1	55.8	9.6	36.3	15.7	40.1
Mannose	15.8	41.1	15.7	40.9	15.1	39.9	20.9	60.3	0.5	53.0
Arabinose	5.6	1.8	0.8	0.6	...	0.1	5.4	0.6	4.2	0.6
Xylose	49.2	39.0	64.4	10.8	65.4	3.8	55.5	1.6	74.3	5.9

[a] No correction made for sugar destruction during hydrolysis.

Results

The results of the investigations have been tabulated in the 22 tables which are part of this report.

Occasional irregularities persisted in the sugar determinations and in the blanks, although the paper (Whatman No. 1) had been washed twice with water. These were particularly noticeable when large amounts of glucose were present. It seems probable that sheet formation may be a major factor in these variations.

Recent work to improve methods on quantitative sugar determinations is directed toward improvements on the sheet texture and reduction of background color. The yield and the sugar ratio of those hemicelluloses which were isolated from the 5 samples are tabulated in Tables I and II. The data on yields of residues and hemicelluloses, their sugar ratios and conditions of consistency during alkaline extraction for treatment I are to be found in Tables III–VI, for treatment II in Tables VII–X, for treatment III in Tables XI–XIV, and for treatment IV in Tables XV–XVIII.

Table X. Consistencies During Treatment II

S_1–S_5 expressed in % w/v[a]

Sequence of extn.	S_1	S_2	S_3	S_4	S_5
At start of 1st KOH extn.[b]	1.81	1.57	1.61	1.81	1.72
At start of 1st NaOH extn.[c]	0.72	0.81	0.85	0.69	0.87

[a] Weight of airdry chlorite holocellulose and residual cellulose, respectively.
[b] 3.4 *N* KOH, i.e., 16.66% w/w or 193 g. KOH (85% assay) per liter.
[c] 3.4 *N* NaOH, i.e., 11.95% w/w or 135 g. NaOH (97% assay) per liter.

In Table XIX a comparison of the composition of the hemicelluloses from various sequences of the four treatments is shown. The composition after the first sequence (potassium hydroxide) of treatments II and III should have been the same. It is not clear why this is not always the case. This may be due to variability in the chromatographic method, in the sample composition, or in the degree of extraction. Room temperature was not controlled during the extraction.

Table XX shows the final result, i.e., the efficiency of the mannose and xylose removal of the four treatments that were to be compared. This table provides also the information at what losses of material these removals were achieved. No attempt was made to determine the D.P. changes that may have occurred during the removal of mannose. Treatment I was superior to any of the other treatments for removing mannose; treatment II for xylose. Xylose, which can be removed in equal degrees by the hydroxides of lithium, sodium or potassium (*8*) seems less easily removed by borate treatments, especially with the potassium hydroxide prior extraction. In treatment III, the removal of mannose with borate also appears to be blocked by the foregoing potassium hydroxide sequences. [In (*1*) similar results were obtained.]

Discussion

The results of these studies corroborate, in general, those of the previous investigation (*1*). Certain specific aspects deserve a little elaboration.

Under the conditions used, the extracted cellulose did not usually change in composition after the third extraction. The number of extractions could certainly be reduced. No attempt has been made to establish optimum conditions of extraction.

Considering the number of extractions, the yields are reasonable. How much glucose is chemically combined with mannose is not definitely known, but we can make the assumption, as does Timell (*9*), that one mole glucose is associated with three moles mannose in the hemicelluloses. In this case the potassium borate extraction shows almost no extraction of glucose other than glucomannan from the pulps and but little more from the wood. It is probably safer, however,

Table XI. Yields of Residual Cellulose and Hemicellulose after Treatment III (KOH-Borate)

S_1 S_5

	S_1		S_2		S_3		S_4		S_5	
Yield residual cellulose, %	61.42		81.71		85.16		61.14		86.15	
Loss, total, %	38.58		18.29		14.84		38.86		13.85	
Loss, in 5 KOH treatments, %	33.79		13.36		10.18		34.63		12.55	
Loss, in 3 borate treatments, %	4.79		4.93		4.66		4.23		1.30	
Hemicellulose, total, %	26.93		7.96		9.79		26.75		9.89	
Unaccounted for, %	11.65		10.33		5.05		12.11		3.96	
Hemicellulose from KOH, %	22.43		4.88		5.18		22.68		8.60	
Hemicellulose from 1st borate, %	3.36		2.74		3.99		5.13		0.51	
Hemicellulose from 2nd borate, %	1.14	4.50	0.82	3.56	1.14	5.13	1.10	6.23	0.97	1.48

to make no assumptions and simply to point out that yields are higher with the borate extractions (III and IV) than with the sodium hydroxide extractions (I and II). Yields are, except for the sulfide pulp S_3, slightly higher in the alkali extractions if potassium hydroxide precedes sodium hydroxide.

In spite of this fact, removal of mannose seems to be a little better if the sodium hydroxide is first. This may be related to the much greater inhibiting effect of preliminary extraction with potassium hydroxide on the potassium borate extraction (*1*), which was again borne out in the present work. No similar effect was observed for xylose. This inhibition is not readily explained, but it must be great if it affects even the powerful swelling and extractive action of sodium hydroxide. The amounts of mannose and xylose remaining in the pulps after treatment I (sodium hydroxide–potassium hydroxide) is within the sensitivity of the chromatographic method, which is about 0.5%.

The composition of the extracted hemicelluloses is extremely interesting. The most striking point is the composition of the material obtained in the potassium hydroxide–potassium borate sequence. With sulfite pulps, the potassium hydroxide removes nearly all the xylose, so that the borate stage gives a practically pure glucomannan. The only contaminating sugar is xylose and this occurs in smaller amounts here than in most of the spruce glucomannans described in the literature, even after purification or fractionation (*9–16*).

Meier, working with pine, has used a similar process. His glucomannan contains galactose, arabinose, and xylose. This is similar to the material obtained from sprucewood holocellulose by ourselves (*1*) and others (*9*, *12*, *14*). These other sugars may be integral parts of the glucomannan molecule or simply sorbed impurities. The ease of hydrolysis may explain their absence from the corresponding extract with sulfite pulps. They have been shown to be removed by some purifications (*9*), and not by others (*12*, *14*). They are not necessarily entirely absent from the pulp, for they are present in the isolated hemicelluloses, but they are present in amounts too small for detection by our present methods.

Another interesting point is brought out by comparing the material extracted with potassium borate and that extracted with sodium hydroxide from holocellulose already extracted with potassium hydroxide. The former contains three mannoses to every glucose, the latter much fewer, from one to two mannoses per glucose. It is clear, from these figures and the yields, that the sodium hydroxide removes some 10% more of the holocellulose than the borate and that this contains a higher percentage of glucose. It will be interesting to use a potassium hydroxide–potassium borate–sodium hydroxide sequence and to examine more closely the sodium hydroxide extract. It is possible that sodium hydroxide has a degrading effect on the cellulose, but it seems more likely, on the basis of the present admittedly insufficient evidence, that there is a glucose-

Table XII. Sugar Ratio of Residual Cellulose—Treatment III

S_1–S_5[a]

	S_1			S_2			S_3			S_4			S_5		
Extracted	*Glucose*	*Mannose*	*Xylose*	*Glucose*	*Mannose*	*Xylose*	*Glucose*	*Mannose*	*Xylose*	*Glucose*	*Mannose*	*Xylose*	*Glucose*	*Mannose*	*Xylose*
1 time with KOH	85.9	13.2	0.9	93.5	6.1	0.4	95.0	4.5	0.5	86.8	12.7	0.5	91.8	6.9	1.3
5 times with KOH	87.4	12.0	0.6	94.2	5.3	0.5	94.6	5.1	0.3	88.4	10.9	0.7	91.5	7.7	0.8
3 times with borate	90.7	8.5	0.8	95.2	3.7	1.1	94.3	5.2	0.5	91.2	8.2	0.6	92.8	6.5	0.7

[a] No correction made for destruction of simple sugars during hydrolysis.

Table XIII. Sugar Ratio of Hemicellulose—Treatment III

S_1–S_5[a]

	S_1 after		S_2 after		S_3 after		S_4 after		S_5 after	
Sugar	*1 × KOH*	*1 × borate*	*1 × KOH*	*1 × borate*	*1 × KOH*	*1 × borate*	*1 × KOH*	*1 × borate*	*1 × KOH*	*1 × borate*
Galactose	15.7	2.2	2.5	...	0.4	...	10.3	1.9	3.5	...
Glucose	11.5	16.4	19.5	25.3	20.6	27.0	10.7	21.6	11.3	34.1
Mannose	25.4	61.6	18.9	74.1	15.2	72.2	22.3	75.9	13.0	59.7
Arabinose	8.2	...	1.4	...	0.5	...	5.9	...	5.0	...
Xylose	39.2	19.8	57.7	0.6	63.3	0.8	50.8	0.6	67.2	6.2

[a] Not corrected for destruction of sugars during hydrolysis.

Table XIV. Consistencies in Treatment III

S_1–S_5 expressed in % w/v[a]

Sequence of extn.	S_1	S_2	S_3	S_4	S_5
At start of 1st KOH extn.[b]	1.8	1.6	1.6	1.8	1.7
At start of 1st borate extn.[c]	5.0	5.0	5.0	5.0	5.0

[a] Weight of airdry holocellulose and residual cellulose, respectively.
[b] The same consistencies were employed as in treatment II. KOH solution was 3.4 *N*, i.e., 16.66% w/w or 193 g. KOH (85% assay) per liter.
[c] The alkaline solution contained 223 g. KOH (85% assay) and 120 g. boric acid (H_3BO_3) dissolved in 1000 ml. water.

Table XV. Yield of Residual Cellulose and Hemicellulose—Treatment IV

S_1–S_5[a]

	S_1	S_2	S_3	S_4	S_5
Yield residual cellulose, %	57.90	86.52	85.74	57.80	84.23
Loss, total, %	42.10	13.48	14.26	42.20	15.77
Hemicelluloses recovered, %	42.10	11.84	11.84	42.20	14.49
Unaccounted for, %	...	1.64	2.42	0.00	1.28
Hemicelluloses after 1st borate extn., %	36.39	9.55	10.00	34.86	12.19
Hemicelluloses, after 2nd and 3rd extns., %	5.71	2.29	1.84	7.34	2.30

[a] Figures based on chlorite holocellulose, *not* on original materials.

rich hemicellulose in the holocellulose that can be obtained in this way.

The two different samples of sprucewood, S_1 and S_4, behave similarly toward treatments I and IV. We do not presently have any explanation for the high xylose contents in the hemicelluloses obtained from S_1 by treatments II and III.

The differences between kraft and sulfite pulps and between sodium and potassium hydroxide extractions are the same as found in the previous investigation (*1*). The inhibiting effect of potassium hydroxide on subsequent removal of mannose is very clear, although the extractive power of sodium hydroxide is almost enough to overcome it.

Table XVI. Sugar Ratios of Residual Cellulose—Treatment IV

S_1–S_5[a]

Sugar	S_1	S_2	S_3	S_4	S_5
Galactose	...	...	...	0.5	...
Glucose	94.5	97.6	98.0	97.5	98.1
Mannose	4.3	1.7	1.4	1.6	1.3
Arabinose	0.3	...	...	...	...
Xylose	0.9	0.7	0.6	0.4	0.6

[a] Not corrected for destruction of sugars during hydrolysis.

MATERIAL BALANCE DURING ALKALINE EXTRACTIONS OF SPRUCE HOLOCELLULOSE

In the preceding section, as well as in the previous publication (*1*), it can be noted that the recovered hemicelluloses did not account for the entire material extracted. Presumably, the difference was due to dissolved material in the mother liquor from the hemicellulose precipitation, but it seemed desirable to check this assumption. This was done by repeating treatment II of the previous section on pulp S_1, with suitable modification to obtain more complete recovery. As is shown in Table XXI, the assumption was verified.

The results prove that in precipitating hemicelluloses with ethanol, a final concentration of about 70% by volume is not always enough to precipitate the hemicelluloses completely. By evaporation of the resulting filtrates from the precipitations, a practically complete recovery of the hemicellulose was obtained in the present experiment.

Table XVII. Sugar Ratios of Hemicelluloses—Treatment IV

S_1–S_5[a]

Sugar	S_1	S_2	S_3	S_4	S_5
Galactose	5.3	1.3	0.2	7.0	2.7
Glucose	41.4	18.1	19.9	12.9	12.6
Mannose	28.3	54.3	50.2	52.4	42.4
Arabinose	4.1	0.2	...	3.8	2.5
Xylose	20.9	26.1	29.7	23.9	39.8

[a] Not corrected for destruction of sugars during hydrolysis.

Table XVIII. Consistencies in Treatment IV

S_1–S_5[a] expressed in % w/v[a]

Sequence of extn.	S_1	S_2	S_3	S_4	S_5
At start of first 2-hr. extn.[b]	4.6	4.7	4.7	4.7	4.7
At start of second 2-hr. extn.[b]	3.0	4.3	4.3	3.0	4.2
At start of 24-hr. extn.	2.8	4.2	4.2	2.8	4.1

[a] Weight of airdry chlorite holocellulose and residual cellulose, respectively.
[b] Alkaline solution prepared from 223 g. KOH (85% assay) and 120 g. boric acid (H_3BO_3), dissolved in 1000 ml. water.

Experimental

The sprucewood used was S_1 from the previous work. The purification followed TAPPI Standards T 12 m-45

Table XIX. Comparison of the Composition of Extracted Hemicelluloses in Treatments I–IV

S_1–S_5

Sample	*Treatment*	*Extraction stage*	*Galactan, %*	*Glucan, %*	*Mannan, %*	*Araban, %*	*Xylan, %*	*Extraction stage*	*Galactan, %*	*Glucan, %*	*Mannan, %*	*Araban, %*	*Xylan, %*
	I	First + 2nd NaOH	6.0	18.5	48.9	3.3	23.3						
S_1	II	First KOH	5.6	24.2	16.0	5.5	48.7	First NaOH	1.5	16.8	41.4	1.8	38.5
	III	First KOH	15.9	11.6	25.7	8.1	38.7	First borate	2.2	16.5	61.9	...	19.4
	IV	First borate	5.3	41.6	28.5	4.0	20.6						
	I	First + 2nd NaOH	...	45.1	35.9	...	19.0						
S_2	II	First KOH	0.4	19.0	15.9	0.8	63.9	First NaOH	0.6	47.2	41.0	0.6	10.6
	III	First KOH	2.5	19.8	19.1	1.4	57.2	First borate	...	25.3	74.1	...	0.6
	IV	First borate	1.3	18.2	54.6	0.2	25.7						
	I	First + 2nd NaOH	0.1	41.4	40.2	...	18.3						
S_3	II	First KOH	0.4	19.4	15.3	...	64.9	First NaOH	0.4	55.9	39.9	0.1	3.7
	III	First KOH	0.4	20.9	15.4	0.5	62.8	First borate	...	27.0	72.2	...	0.8
	IV	First borate	0.2	20.0	50.5	...	29.3						
	I	First + 2nd NaOH	6.1	17.4	42.0	3.6	30.9						
S_4	II	First KOH	8.7	9.7	21.2	5.4	55.0	First NaOH	1.2	36.3	60.3	0.6	1.6
	III	First KOH	10.4	10.8	22.6	5.8	50.4	First borate	1.9	21.6	75.9	...	0.6
	IV	First borate	7.0	13.0	52.8	3.7	23.5						
	I	First + 2nd NaOH	1.2	36.6	30.5	1.4	30.3						
S_5	II	First KOH	5.4	16.0	0.5	4.2	73.9	First NaOH	0.4	40.2	53.1	0.6	5.7
	III	First KOH	3.5	11.5	13.2	5.0	66.8	First borate	...	34.2	59.8	...	6.0
	IV	First borate	2.7	12.7	42.8	2.5	39.3						

Table XX. Comparison of the Efficiency of Treatments I–IV

S_1–S_5 in the removal of mannose and xylose

Sample	Treatment	Removal of Mannose, %	Removal of Xylose, %	Yield, % of holocellulose
S_1	I	95.6	98.6	54.85
	II	93.8	99.4	52.98
	III	67.8	94.5	61.42
	IV	84.6	94.2	57.90
S_2	I	97.0	96.9	79.88
	II	94.5	98.6	73.84
	III	62.2	82.9	81.71
	IV	81.6	88.2	86.00
S_3	I	97.1	97.8	74.78
	II	97.1	97.8	77.48
	III	40.7	88.7	85.16
	IV	84.2	86.2	85.74
S_4	I	94.4	98.4	55.28
	II	91.1	98.5	51.10
	III	60.8	94.9	61.14
	IV	92.8	96.7	57.80
S_5	I	94.7	97.6	78.25
	II	92.0	97.8	74.05
	III	24.3	91.3	86.15
	IV	85.3	92.6	84.23

and T 11 m-45. Only the wood meal retained on mesh no. 60 was taken for the purification, which also included a hot water extraction. The extractions were done at 23° ± 0.2°C., stirring at 6 r.p.m. under nitrogen. The moisture determinations were made on the air-dried material, and airdrying was done always at 54% R.H. Yields of extracted holocellulose were determined after the total potassium hydroxide extraction and again after the total sodium hydroxide extraction. The hemicelluloses after the first potassium hydroxide as well as after the first sodium hydroxide extraction were precipitated after acidification with 3 volumes of 95% ethanol giving a final ethanol concentration of at least 68% by volume and isolated separately. Precipitation of the other hemicelluloses was done in the same way except that the precipitates were combined in the case of the last four potassium hydroxide and of the last three sodium hydroxide extractions.

The filtrates of the entire five potassium hydroxide extractions and of the entire four sodium hydroxide extractions were evaporated until crystallization began. Water was added to complete solution and aliquots taken. These were deionized by passing through an IR-120 column and then evaporated at 30°C. to dryness. The residue was dried over calcium oxide at about 15 μ

Table XXI. Material Balance on Extraction of Sprucewood Holocellulose Extracted Successively with Potassium and Sodium Hydroxide[a]

Material	Without recovery of solubles		With recovery of solubles	
Residual cellulose, %	52.98		55.91	
Total extract, %		47.02		44.09
Details of Recovery				
After 1st KOH extn., %	12.42		17.03	
After other KOH extns., %		Not. detd.	1.51	
Soluble hemicelluloses from filtrate, %		Not detd.	11.29	
After 1st NaOH extn., %	15.64		10.31	
After other NaOH extns., %		Not detd.	1.05	
Soluble hemicelluloses in filtrate, %		Not detd.	1.61	
Material balance, %	81.04		98.71	

[a] All percentages on basis of ovendry holocellulose.

Table XXII. Recovery of Hemicellulose from Potassium Hydroxide and Sodium Hydroxide Extraction[a]

Material	Without recovery of solubles	With recovery of solubles
Total loss on KOH extn., %	28.04	31.23
Recovered hemicellulose, %	12.42	29.83
Unaccounted for, %	15.62	1.40
Total loss on NaOH extn., %	18.98	12.86
Recovered hemicellulose, %	15.64	12.86
Unaccounted for, %	3.34	...

[a] All percentages on basis of ovendry holocellulose.

pressure at room temperature. The yields in Table XXI are based on this residue. The dried material from the five potassium hydroxide extractions was brownish and of a somewhat oily appearance. The color was not removed by carbon tetrachloride, but dissolved readily in absolute ethanol, leaving the material white. A qualitative chromatographic test of this residue showed only very faint amounts of low molecular weight carbohydrates. A qualitative chromatogram of the dried material, after hydrolysis, showed spots corresponding to galactose, glucose, mannose, arabinose, and xylose. Glucose, mannose, and xylose appeared to be present in roughly equal amounts. Galactose and arabinose were present in smaller amounts, each about the same. There were traces of slower moving substances, probably disaccharides, but no evidence of uronic acids.

The residue from the four sodium hydroxide extractions was also brown. A qualitative test by chromatography showed no free sugars, but there was so little that it was not hydrolyzed.

Results and Discussion

The amount of extractives was 4.95% of the ovendried wood and the yield of holocellulose was 70.48%. The material balance on the extraction of the holocellulose given in Table XXII breaks down the percentage unaccounted for into the two stages of the extraction. It will be seen from these tables that the bulk of the material not accounted for in the earlier experiment comes from the potassium hydroxide extraction and can be attributed to solubility in the mother liquor from the hemicellulose precipitation.

The large amount of hemicelluloses soluble in 70% ethanol is unusual. Perhaps it may be attributable to the fact that there were no preliminary extractions with more dilute alkali. In the more usual procedure, the dilute alkali removes some hemicelluloses which never come into contact with the stronger solution. In the present case these may be degraded to an alcohol-soluble stage.

If the emphasis were on fractionation and complete recovery of the hemicelluloses, the conventional procedure would be preferable. If, as here, the primary purpose is to free the residual cellulose from nonglucose sugar units, some modification of the procedure used here would seem advantageous.

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Received Nov. 10, 1959.

The Solubility of Sodium Carbonate in Sodium Sulfide Solutions

S. T. HAN and ROY P. WHITNEY

The solubility of sodium carbonate in sodium sulfide solutions was determined at temperatures from 5 to 90°C. and with a sulfide content from 2 to 10%. The solubility behavior of the Na_2CO_3-Na_2S-H_2O system in this range is very similar to that of the Na_2CO_3-H_2O system. Above approximately 35°C., there is a stable region in equilibrium with monohydrate. Below 35°C., appear a stable region in equilibrium with decahydrate and a metastable region of β-heptahydrate. The application of the solubility data to the kraft-neutral sulfite cross recovery is briefly discussed with respect to fractional crystallization and partial solution.

The system, Na_2CO_3–Na_2S–H_2O, is of particular interest to the pulp industry. The smelt solution or green liquor resulting from burning a spent pulping liquor under a reducing atmosphere is essentially an aqueous solution of sodium carbonate and sodium sulfide. By appropriate chemical treatment of the smelt solution, the pulping liquor may be regenerated. The desired cooking chemicals are sulfide and hydroxide in the kraft process, sulfite, carbonate and bicarbonate in the neutral sulfite process, and bisulfite and sulfurous acid in the acid sulfite process.

In the so-called cross recovery, the neutral sulfite spent liquor is used as a make-up in a kraft recovery system. Obviously, in such a case, the size of the neutral sulfite production which may be integrated with a given kraft production is limited by the sodium loss in the joint recovery system. To overcome this difficulty, it has been suggested (*1*, *2*) that sodium carbonate be partially removed from the smelt solution, leaving a liquor of a higher sulfidity* for use in kraft cooking. The sodium carbonate thus separated is used for the preparation, by direct sulphitation, of fresh neutral sulfite cooking liquor.

Phase separation requires a knowledge of the equilibrium relationships. This study was undertaken to establish the solubility of sodium carbonate in sodium sulfide solutions in the composition and temperature ranges concerned.

Before presenting the results, it is deemed appropriate to review the simpler Na_2CO_3-H_2O system for which extensive solubility data are available. Figure 1 shows the solubility of sodium carbonate in water based on the data quoted from the International Critical Tables (I.C.T.). It is seen that the solubility curve consists of three stable regions: the decahydrate ($Na_2CO_3 \cdot 10H_2O$), the β-heptahydrate ($Na_2CO_3 \cdot 7H_2O\beta$), and the monohydrate ($Na_2CO_3 \cdot H_2O$), the transition points being 32.00 and 35.37°C., respectively. Below the second transition point, there are several metastable regions, notably the heptahydrates in both α- and β-forms.

It is of interest to note that, although the solubility of sodium carbonate increases markedly with increasing temperature in the deca- and heptahydrate regions, it actually decreases slightly above the second transition point. On the other hand, the solubility of sodium sulfide is known to increase strongly throughout a comparable temperature range.

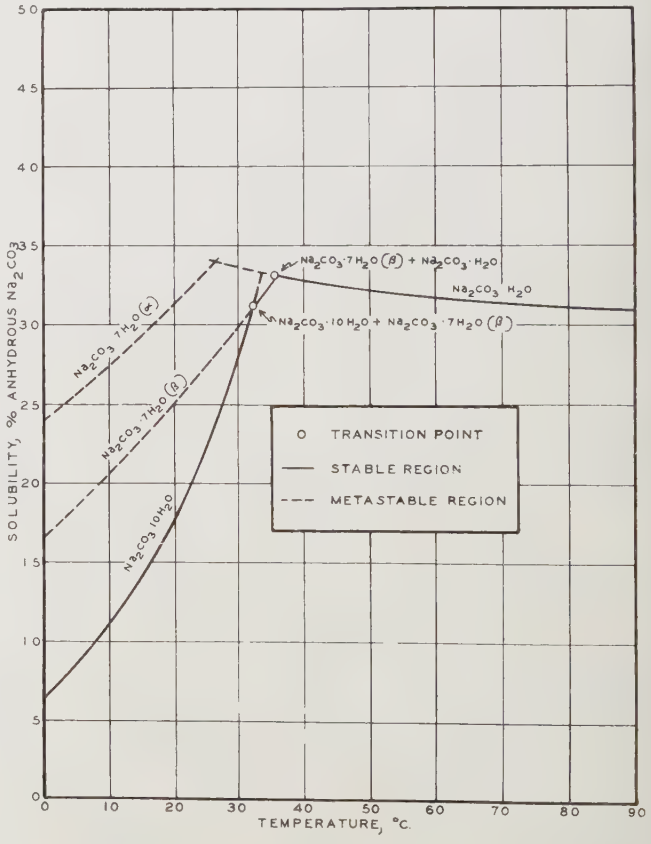

Fig. 1. The solubility of sodium carbonate in water (data from I.C.T.)

S. T. Han, Research Associate, and Roy P. Whitney, Vice-President and Dean, The Institute of Paper Chemistry, Appleton, Wis.

* Sulfidity is defined as the molal percentage of sodium sulfide in a mixture of sodium sulfide and sodium carbonate.

Table I. Solubility of Sodium Carbonate in Sodium Sulfide Solutions

Temperature, °C.	Composition by weight		
	Na_2CO_3, %	Na_2S, %	H_2O, %
5	3.2	11.7	85.1
	3.8	7.8	88.4
	5.2	4.3	90.5
10	4.5	11.0	84.5
	5.6	7.3	87.1
	7.2	4.2	88.6
15	7.3	10.0	82.7
	8.7	6.3	85.0
	10.4	3.7	85.9
20	10.9	8.9	80.2
	12.4	5.6	82.0
	14.0	3.2	82.8
25	17.3	8.2	74.5
	17.6	8.0	74.4
	18.3	7.2	74.5
	19.5	5.9	74.6
	19.8	5.9	74.3
	20.4	5.3	74.3
	22.0	4.0	74.0
	22.9	3.2	73.9
	23.3	2.8	73.9
	27.4	0.0	72.6
30	21.0	7.3	71.7
	21.3	7.0	71.7
	23.6	5.0	71.4
	23.5	5.0	71.5
	25.8	3.0	71.2
35	17.7	9.3	73.0
	22.3	6.5	71.2
	26.1	4.0	69.9
40	17.2	9.4	73.4
	21.7	6.6	71.7
	25.7	4.1	70.2
50	16.5	9.4	74.1
	20.9	6.6	72.5
	25.0	4.1	70.9
70	15.3	9.7	75.0
	20.0	6.9	73.1
	23.8	4.2	72.0
90	15.4	9.6	75.0
	19.6	6.8	73.6
	23.6	4.2	72.2

In the metastable regions, the system is not in a true thermodynamic equilibrium, but it is, nevertheless, fairly stable with regard to the imposed conditions. A metastable state is generally one of supersaturation because of the inertia of the system in the course of a transition. In Fig. 1, the metastable curves seem to be simply natural extensions of the stable regions.

EXPERIMENTAL

The solutions were prepared by dissolving sodium carbonate and sodium sulfide in distilled water. The reagent-grade sodium sulfide used in the preparation was found to contain appreciable quantities of impurities, mainly sodium thiosulfate and sodium sulfite. The initial solutions were supersaturated in sodium carbonate with respect to the temperature at which the solubility was to be determined.

The bottles containing the prepared solutions were rotated in a thermostat maintained at the desired temperature within 0.2°C. It was found that a period of 8 hr. was generally sufficient to attain equilibrium. A sample of the supernatant solution was then carefully removed from the bottle with a sintered-glass dispersion tube, while the bottle remained in the thermostat.

The sample was analyzed for sodium carbonate and sodium sulfide by the conventional methods, and its density was determined pycnometrically. The results of analysis were expressed in weight per cent, the impurities being combined with water. The solid phase was not analyzed.

The temperature range covered was from 5 to 90°C., and the sulfide content in the solution up to 12%. The complete data of the solubility determinations are presented in Table I.

DISCUSSION OF RESULTS

The solubility data for a condensed ternary system can be represented concisely on a triangular diagram. In such a diagram, each side of an equilateral triangle is a co-ordinate designating the weight percentage of one component. A point within the triangle thus represents a ternary composition, and a point on a side, a binary composition. A curve joining the isothermal points represents the solubility of one component at a definite temperature.

The solubility data of Table I were so plotted on a triangular diagram which revealed a solubility behavior very similar to the Na_2CO_3-H_2O system previously described. There appeared three distinct families of curves falling into three ranges of temperatures, namely, 5 to 20, 25 to 30, and 35 to 90°C. For the sake of clarity, as well as for convenience of discussion, the results are presented in three separate diagrams, Figs. 2, 3, and 4, pertaining to these temperature ranges, respectively.

To complement the solubility information, the composition of the solid phase must be specified. In view of the close similarity between the present system and the Na_2CO_3-H_2O system, the hydrate form in each of the three temperature ranges was taken to be the same as the latter system. In Figs. 2 to 4, the solubility values of sodium carbonate in water at the corresponding temperatures are included. It is seen that at each temperature, the present data can be extended to the Na_2CO_3 axis by a smooth curve, and each family of the extended curves appears to be internally consistent.

In the low-temperature range from 5 to 20°C., the solid phase consists of sodium carbonate decahydrate ($Na_2CO_3 \cdot 10H_2O$). The solubility of sodium carbonate decreases, to a progressively lesser extent, with increasing sulfide content. The solubility in the high-temperature range from 35 to 90°C. decreases slightly with temperature, almost in quantitative agreement with the Na_2CO_3-H_2O system. The solid phase is therefore monohydrate (Na_2CO_3-H_2O). The effect of sulfide content appears to be more pronounced than in the low-temperature region, as will be shown later.

The experimental data at the two intermediate temperatures of 25 and 30°C. appear, at first, to be inconsistent with those at lower temperatures. The intersection of the extended curves at the Na_2CO_3 axis, however, indicates that both are in the metastable region, the solid phase being β-heptahydrate ($Na_2CO_3 \cdot 7H_2O\beta$). This is due to the experimental approach to equilibrium from a supersaturated condition through a transition range. Using the same approach, one run was made for sodium carbonate in water at 25°C. The result of the run agreed closely with the known solubility value for β-heptahydrate, as shown in Fig. 3.

All the curves, if extended toward the H_2O axis, will sooner or later meet a eutectic line along which the solution is in equilibrium with both sodium carbonate and sodium sulfide in solid phases. This region was not investigated. Some data in this region have been obtained by Martin, Felicetta, and McCarthy (*3*).

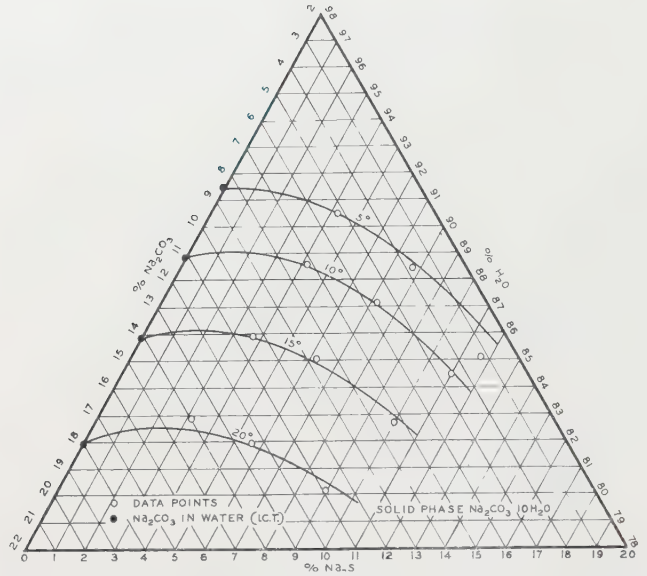

Fig. 2. The solubility of sodium carbonate in sodium sulfide solutions (5–20°C.)

The present data are in good agreement with theirs in the common range.

Figure 5 shows the solubility relationships for the present system in the complete temperature and composition ranges investigated on the basis of the smoothed data presented in the previous figures. The solid curves represent the stable regions and the broken curves, the metastable region. The low-temperature data are extrapolated, as shown by the dotted curves, to show the trend of the missing data. The similarity between the pure sodium carbonate curve (0% Na_2S) and the remaining curves at the various percentages of sodium sulphide are especially prominent in this plot.

The effects of sulfide content on the solubilities in all the regions are brought out clearly. As the sulfide percentage increases, the solubility of carbonate decreases, but to a progressively lesser extent. The most pronounced effect of the sulphide content is in the monohydrate region.

It is also of interest to note the progressive shift of the hypothetical monohydrate-heptahydrate transition point to a lower temperature with increasing sulfide content. If such a shift is real, the stable heptahydrate region would tend to become shortened as the sulfide content increases, until the two transition points verge into a single one. The result would be the absence of a stable heptahydrate region in the Na_2CO_3-Na_2S-H_2O system.

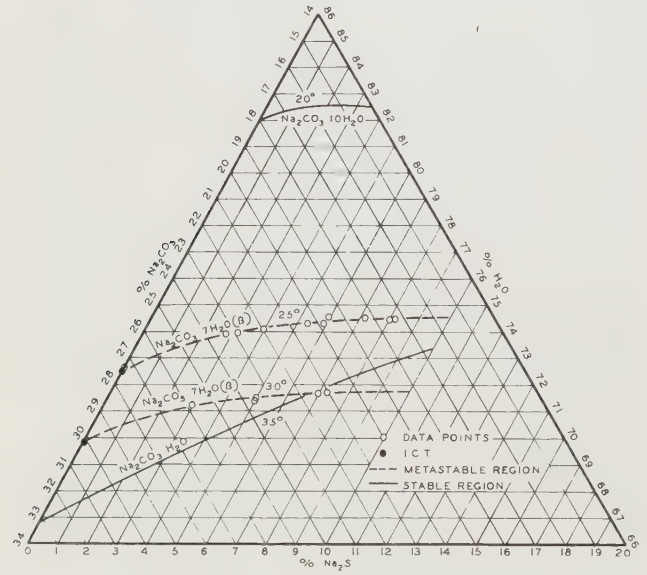

Fig. 3. The solubility of sodium carbonate in sodium sulfide solutions (25–30°C.)

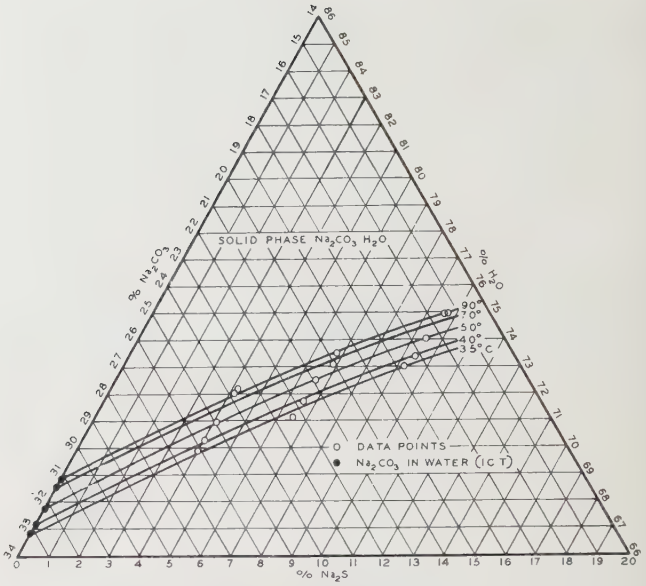

Fig. 4. The solubility of sodium carbonate in sodium sulfide solutions (35–90°C.)

Application to Cross Recovery

The essential feature of cross recovery, as previously mentioned, is the use of a neutral sulphite spent liquor as a make-up for kraft recovery. In a conventional manner, the amount of neutral sulfite liquor that may be utilized is limited to the sodium make-up of the joint recovery system. The sodium losses are usually very

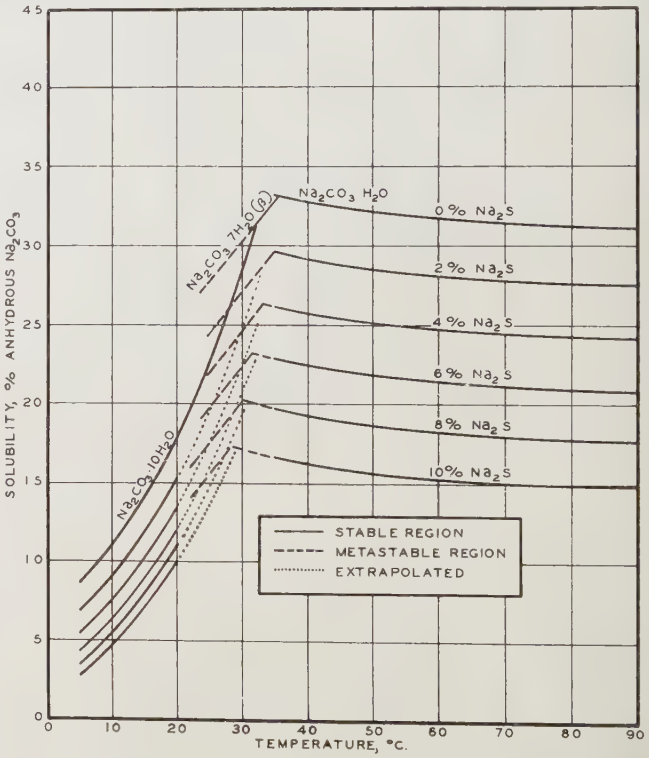

Fig. 5. The solubility of sodium carbonate in sodium sulfide solutions (5–90°C.)

low, about 7 to 15%, as compared with the sulfur losses of 30 to 40%. Obviously, a great deal more neutral sulphite liquor can be used for sulfur make-up, provided that the excess sodium so introduced to the kraft smelt may be removed.

For the purpose of illustration, if a kraft production requires 620 lb. Na_2O and 96 lb. sulfur per ton of pulp, and if the recovery system operates in a steady state at a sodium loss of 10% made up by sodium sulphate, the sulfur loss must amount to 32 lb. per ton of pulp or 33.3%. Assuming that a neutral sulfite pulp requires 217 lb. Na_2O and 96 lb. sulfur per ton of pulp, the maximum neutral sulfite production which may be cross-recovered at the same chemical losses for the sodium make up would be only 0.318 per ton of kraft. Furthermore, because of the lower sulfur-sodium ratio in the neutral sulfite liquor, as compared with that in sodium sulfate, the sulfidity of the resultant kraft smelt would be lower. On the other hand, if the neutral sulfite liquor is used for the sulfur make-up, the neutral sulfite production could be increased to 0.5 ton per ton of kraft, and the sulfidity of the kraft smelt would remain unchanged. In this case, the excess sodium supplied to the smelt would be 35 lb. Na_2O or 60 lb. Na_2CO_3 per ton of kraft, which must be removed prior to the causticization.

There are three common methods of separating a solid phase from a liquid, namely, fractional crystallization, evaporation, and partial solution. In fractional crystallization, the smelt is cooled until the required amount of carbonate is crystallized. Recalling the solubility characteristics of the system, it is apparent that such a process to be effective must be employed in the low-temperature range in which the solubility of sodium carbonate decreases rapidly with decreasing temperature. To cool a hot smelt solution to such a low temperature not only requires a large heat transfer area, but also involves the passing of the transition region and possibly results in a metastable state.

A second alternative is to concentrate the smelt solution by evaporation. This requires expenditure of thermal energy, but would avoid the metastable condition.

The most economical method would be to dissolve the molten smelt in a limited amount of water, resulting in a smelt solution saturated with a solid phase of sodium carbonate monohydrate. The advantages of such a method are several. First, since the solubility of sodium carbonate in the monohydrate region varies but slightly with temperature, the control of temperature would not be critical. Second, the process of dissolution is generally easier to conduct than the reverse process of crystallization or precipitation. Third, the overall heat effect would be somewhat smaller. Fourth, the equipment could conceivably be simpler. The chief disadvantage of the method of partial solution would be the contamination of the solid phase resulting from nonuniform operating conditions.

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Received Nov. 13, 1959.

Acknowledgment is made to the Neutral Sulfite Semichemical Recovery Group for permission to publish the results of this work. The assistance of Jack Close and Warren Belanger in the experimental work is gratefully acknowledged.

Microscopic Fusion Analysis

A Potentially Useful Technique for the Pulp and Paper Industry

VICTOR GILPIN

Fourteen compounds, submitted by The Institute of Paper Chemistry, were subjected to microscopic fusion analysis, and found to exhibit characteristics by which each could be readily identified. The particular techniques employed were those developed by American microscopists. These techniques are simple, direct, specific, reliable, and relatively quick; they are believed to be potentially valuable to the pulp and paper industry.

Although various other branches of microscopy have been widely used in the pulp and paper industry, there is no published reference to the use of microscopic fusion analysis in this field. Experience has shown that the techniques which have been developed in this branch of chemical microscopy are applicable to a great variety of pure substances and mixtures. This suggests that microscopic fusion analysis will also be useful to chemists concerned with wood, pulp, and other aspects of the paper industry.

In essence, fusion analysis uses the polarizing microscope to observe all the changes which occur when a substance on a microscope slide is heated to melting and then allowed to cool. Thus fusion techniques are mainly, although not exclusively, concerned with solids. As developed in Austria by the Koflers and their collaborators, these methods are chiefly concerned with behavior during heating. Expensive auxiliary equipment, principally a hot stage, is used, and the operator should have considerable training. The American methods, developed by McCrone and his collaborators, place more emphasis on observations during cooling of the sample. A microflame, as from an alcohol lamp, is the only extra equipment needed, and much useful work can be done by an operator with very little training. The Austrian and American approaches complement each other, and sometimes overlap.

In the American procedure, a few milligrams of substance is placed on a microscope slide and covered with a cover glass. The slide is then held over a microflame until the substance melts. At various stages during heating and cooling the slide is removed to the micro-

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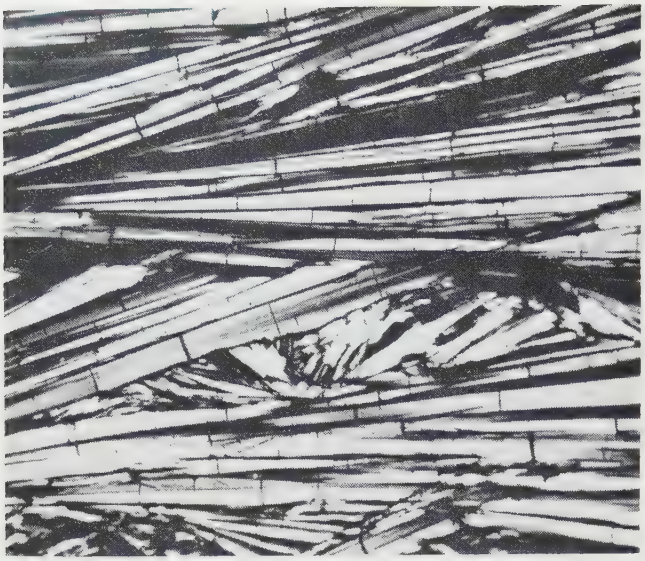

Fig. 1. Alpha-cellobiose octaacetate

scope stage for observation. This technique yields largely qualitative observations of the behavior of a particular compound. The sum of these observations is usually specific for that compound. This generally permits the analyst to identify the compound quickly and easily on subsequent encounters by its familiar appearance. A "library" of known reference compounds is very helpful in this work. If this is not available, descriptions and photographs, such as those that follow, are the best substitutes. It is the purpose of this paper to call attention to the simple procedures and potential usefulness of this type of fusion microscopy. The experiments deal with 14 compounds furnished for this purpose by The Institute of Paper Chemistry.

The theory, techniques, applications, and literature of fusion microscopy have been recently and thoroughly reviewed by McCrone (*1*). Of all the possible observations mentioned by McCrone, only those useful for positive identification have been reported for the present compounds. For example, conoscopic properties (observed with a 0.85 numerical aperture objective) have not been recorded where they were so dim or diffuse as to defy ready recognition. The photomicrographs are, as far as possible, representative of prominent diagnostic features.

Fig. 2. Catechol diacetate (1,2-diacetoxybenzene)

Fig. 3. Vanillin benzoate (4-formyl-2-methoxyphenyl benzoate)

The terminology used in the present study conforms as closely as possible to McCrone (*1*) and to current usage in the field of optical crystallography.

EXPERIMENTAL

Alpha-Cellobiose Octaacetate. The melt tends to supercool slightly. A few nuclei soon appear, and solidification begins fairly slowly. As the temperature falls, the crystallization velocity increases slightly, then decreases again near room temperature. The initial crystals are blades or laths of moderate to narrow width (Fig. 1). At the crystal front the width of the crystals decreases, the number of crystals greatly increases, and the front outline becomes smoother during cooling. Just above room temperature, in the remaining unsolidified melt, a large number of nuclei form, and solidification terminates with the growth of numerous spherules of hairlike crystals radiating from a common center. This stage of solidification will be the only one observed if the original melt supercools greatly.

Crystals generally show a few shrinkage cracks, mostly transverse (Fig. 1). Birefringence is fairly low, and optical extinction is usually not uniform over the whole length of what appears to be a single crystal.

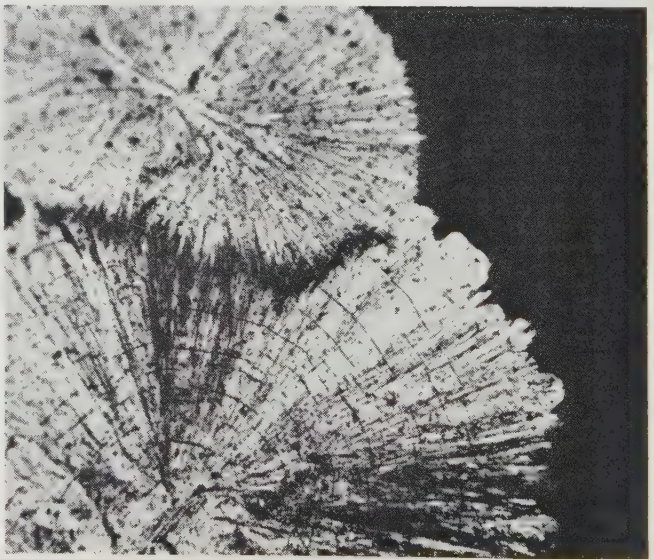

Fig. 4. 3-Methoxy-4-(2,4-dinitrophenoxy)-benzaldehyde

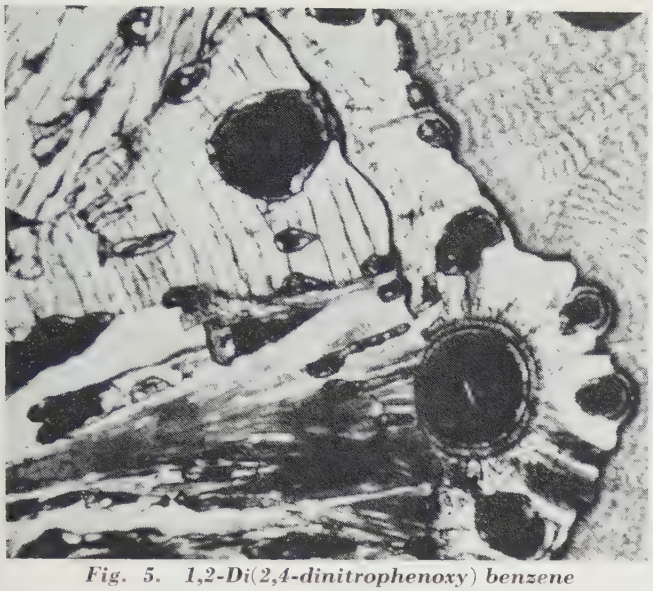

Fig. 5. 1,2-Di(2,4-dinitrophenoxy) benzene

A mixed-fusion preparation with supercooled thymol gives needles and laths of varying width. Some of these crystals are well formed, with more homogeneous optics than crystals from the pure melt. A few of these good crystals show square ends, parallel extinction, and an interference figure of negative sign with one optic axis just at the edge of the field. The optic axial plane is at right angles to the length of the crystal. Other crystals, although superficially similar, show distinct variations. Many crystals in the thymol develop fine wispy, fringes at their terminations.

Catechol Diacetate (1,2-diacetoxybenzene). The melt supercools to room temperature without freezing. On seeding, the melt solidifies at a moderately swift velocity.

From a meltback, solid grows very slowly at first, but the crystallization velocity steadily increases as the temperature falls. The crystals first formed are rods and blades of medium width, with well-defined terminal profile angles. As crystallization proceeds, the individual crystal profiles become less well defined, and the profile of the whole crystal front steadily becomes smoother. Lines of beadlike air bubbles, parallel to the direction of growth, are formed (Fig. 2). The width of the crystals steadily decreases as the crystal front becomes smoother in outline. Very few shrinkage cracks (usually transverse) appear. Crystals of the solid show medium to high birefringence, parallel extinction, and negative elongation. The optic axial plane is parallel to the crystal length.

In a mixed fusion with thymol, well-developed rods and blades grow showing 42 and 84° terminal angles, and optics as described above. The index parallel to the crystal length is less than the melt, and the other index is greater than the melt.

Vanillin Benzoate (4-formyl-2-methoxyphenyl benzoate). The melt supercools to an extremely viscous liquid. After some hours, numerous nuclei appear and grow very slowly. The crystals formed are invariably dendritic, showing straight or curved spines with offshoots (Fig. 3). A very slight increase in crystallization velocity is noticed with increased temperature. Birefringence of the solid is medium to high.

The few optically clear areas show an optic axis just beyond the edge of the conoscopic field. The refractive index in one direction is almost equal to the melt. In the other direction, the crystals show moderate to small contrast.

3-Methoxy-4-(2,4-dinitrophenoxy)-Benzaldehyde. On melting, there is slight decomposition. The liquid supercools to a glass. On warming, a fair number of nuclei of two forms appear and grow. For both types of crystals, the growth velocity is nearly zero at room temperature.

Polymorph A (probably the stable form) grows extremely slowly at higher temperatures as crude spherules of moderately smooth outline. The solid is composed of radiating hairs and needles having sharply pointed ends (Fig. 4). Individual crystals are so intermixed and overlapping that the optics are not discernible. The optical contrast with the melt is moderately good in all directions.

Polymorph B grows slowly at higher temperatures. Its growth rate, however, is appreciably greater than that of form A. The solid is composed of needles and narrow blades of greater width than those in form A (Fig. 4). The crystal profiles are ill defined and do not form so smooth a front as those of form A. Concentric shrinkage cracks appear (Fig. 4). Although the optics are again obscured by intermingled crystals, it is possible to see that the contrast between crystals and melt is very slight in the long crystal direction, and is moderate in the direction normal to the length.

In both forms the birefringence is fairly high. The polymorph transition velocity is negligible at all temperatures below the melting point.

1,2-Di(2,4-dinitrophenoxy) Benzene. The melt supercools to a glass. On warming, a few nuclei grow at a slow rate which reaches a slight maximum between the melting point and room temperature. The solid radiates from a common center in two orientations: (a) as (usually) large wedge-shaped crystals of high birefringence, and fairly uniform extinction (Fig. 5) and, (b) as striated blades showing roughly parallel extinction, medium birefringence, positive elongation, and an off-center Bx_a figure (negative) with one optic axis just at the edge of the field. The optic axial plane is parallel to the length of the blade, and $2E$ is approximately 74°.

The crystal front is scalloped by large air bubbles which are engulfed as crystallization proceeds (Fig. 5). The outline profile of the crystal front is temperature dependent, varying from jagged to smooth and wavy. In the solid, a distinctive pattern of prominent shrinkage cracks appear (Fig. 5). Both refractive indices are greater than the melt.

At room temperature, the unsolidified melt very slowly crystallized as a fine-grained granular mass, parts of which show characteristic wavy structure (Fig. 5).

Syringin. The melt supercools and solidifies to a glass. On warming and seeding narrow blades grow slowly into the viscous melt. The blades radiate in all directions from the seeds. As the temperature cools, the crystallization velocity slows markedly and the blades become the origin of a multitude of tiny hairs and needles. This could be a polymorphic transformation but is more probably a habit change. Continued warming causes the formation of a smooth, continuous crystal front, together with the formation of spherules

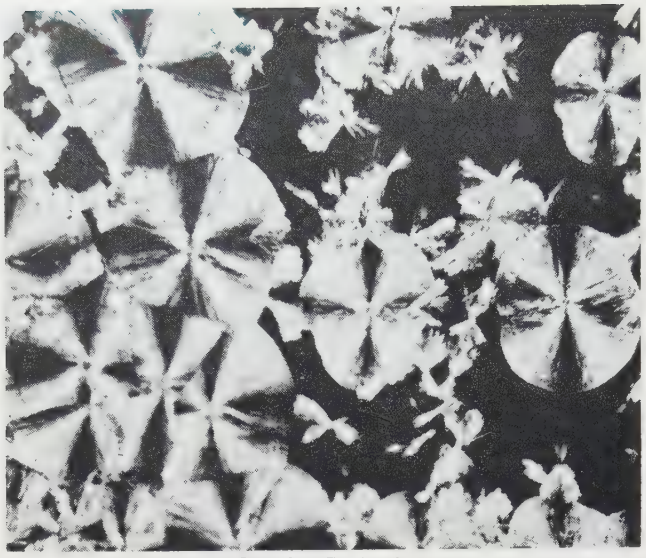

Fig. 6. Syringin

from new nuclei. The spherules of hairlike crystals have a smooth circular outline (Fig. 6). They show the typical extinction cross (Fig. 6), negative elongation, the index in the long crystal direction slightly greater than the melt, the other index considerably greater than the melt. A few concentric shrinkage cracks appear.

The original blades show several orientations. One group has parallel extinction, part with positive elongation, part with negative elongation. Another group exhibits extinction at 25° to the blade axis. Most blades show fairly low birefringence, one index nearly equal to the melt, the other index somewhat greater than the melt. Most blades also show an optic axis just at the edge of the field.

Liriodendrin Octamethyl Ether. The melt supercools slightly. Self-seeding is initiated at several places. Growth continues with radiating narrow blades, moving at moderate crystallization velocity to form large spherules showing the typical extinction cross.

On meltback, narrow blades grow slowly at first. As the temperature falls, the growth rate increases somewhat and crystals become ever narrower and more numerous (Fig. 7). At stilll ower temperatures, the crystallization velocity slows again, and numerous nuclei

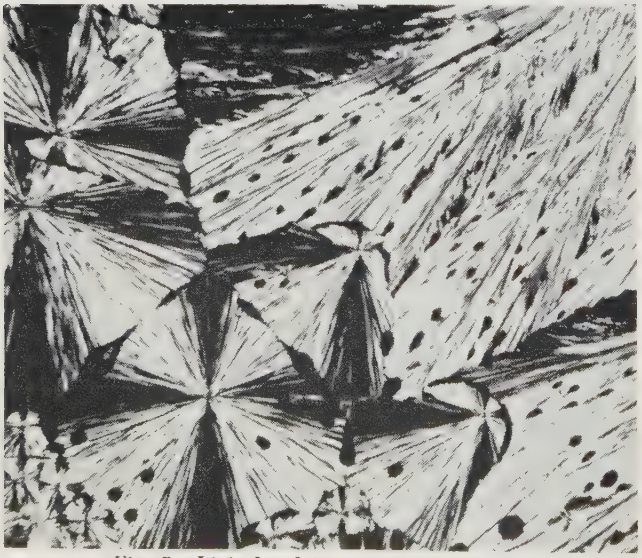

Fig. 7 Liriodendrin octamethyl ether

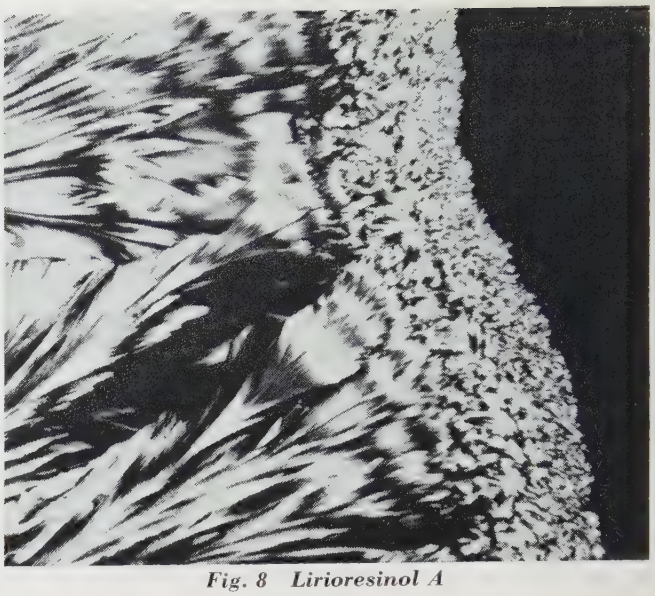

Fig. 8 Lirioresinol A

appear and grow as bladed spherules (Fig. 7). Just above room temperature, the number of nuclei vastly increases and solidification is completed with many tiny spherules. A few transverse shrinkage cracks and some air bubbles appear during cooling (Fig. 7).

Crystals show low to medium birefringence, parallel extinction, negative elongation, and an optic axis at the edge of the conoscopic field. The optical properties are frequently obscured by overlapping crystals.

Lirioresinol A. The melt decomposes slightly and supercools to a glass. A few nuclei appear but do not grow. Warming the slide causes a considerable increase in the number of nuclei and in the crystallization velocity. Growth is in the form of spherules of very tiny radiating hairs. These are so intertwined that the extinction cross is quite indistinct. The spherule boundary is smooth, and crystal birefringence is medium to high. Concentric shrinkage cracks appear. Heating to higher temperatures causes a polymorphic transformation to sweep across the preparation, leaving the spherules as pseudomorphs.

A meltback of the transformed preparation gives small, clear, platelets which grow into broad blades moving slowly. As the temperature falls, the blades grow together to form a smooth front. Blades then begin to twist and curl, and divide into a multitude of

Fig. 9 Lirioresinol A dimethyl ether

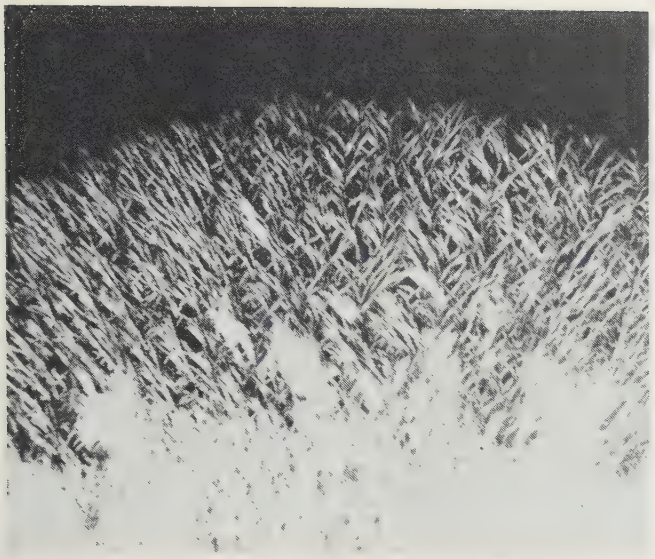

Fig. 10. Lirioresinol A dibromodimethyl ether

curving hairlike crystals in a fan shaped pattern (Fig. 8). As the crystallization velocity slows to zero the front abruptly changes to a fine-grained granular mass (Fig. 8). A complicated pattern of fine cracks appears.

Good crystals show medium birefringence, parallel extinction, negative elongation, and a variety of off-center interference figures.

Lirioresinol A Dimethyl Ether. The melt supercools to room temperature and soon sets to a glass. There is no spontaneous nucleation at any temperature. With seeding and prolonged warming, growth takes place at an exceedingly slow rate. The crystals formed are narrow blades and needles most of which show rather rounded ends (Fig. 9). A few transverse shrinkage cracks appear.

The crystals show parallel extinction, low to medium birefringence, negative elongation, and an optic axis just outside the edge of the field. The refractive index parallel to the crystal length is less than the melt, the index at right angles to it is greater than the melt.

Lirioresinol A Dibromodimethyl Ether. The melt supercools to a glass. No nuclei are formed. With seeding and warming, solid grows in a fashion remarkably like that shown in Fig. 9, with the following modifica-

Fig. 11. Lirioresinol B dimethyl ether

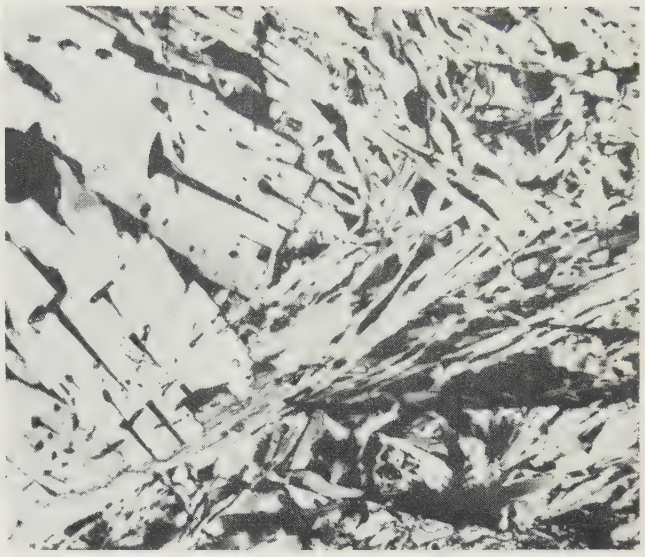

Fig. 12 Lirioresinol B dibromodimethyl ether

tions: morphologically, the present compound shows a tendency to jagged and feathering, rather than rounded, end profiles; the present compound also shows no shrinkage cracks. Optically, crystals of the present compound show a variety of orientations at the principal extinction positions. In addition to these modifications of superficial similarity between these two compounds, the crystallization velocity of the present compound, although low, is very much greater than that of the preceding compound.

A second type of crystallization, which may be a polymorph, also appears. A polycrystalline granular mass slowly grows out into a very distinctive pattern of small curved, interlacing threads and tiny blades, with interstitial liquid (Fig. 10). The solid shows extremely low birefringence. Crystallization velocity is zero at room temperature.

Lirioresinol B Dimethyl Ester. The melt supercools to a glass. When warmed and seeded, crystals grow at a slow velocity which decreases to near zero at room temperature. The growth crystals are of two distinct habits, broad blades of very low birefringence, and much narrower blades of medium birefringence (Fig. 11). Initially, terminal profile angles are clear and distinct. As the temperature falls, the crystal front gradually becomes smooth and continuous. A few air bubbles and shrinkage cracks, mostly transverse, appear (Fig. 11).

The narrower, more highly birefringent blades show parallel extinction, negative elongation, and an indistinct interference figure. The broader blades, of low birefringence, show parallel extinction, negative elongation, and a nearly centered Bx_a figure. $2E$ is about 50° (positive).

When allowed to stand at room temperature, further crystallization slowly occurs as a microcrystalline mass of low and medium birefringent material (Fig. 11).

Lirioresinol B Dibromodimethyl Ether. The melt supercools. Before room temperature is reached a granular mass of solid forms and grows at moderate speed. As the temperature falls, this unoriented mass becomes closely packed threadlike crystals more or less uniformly oriented with their long axes normal to the smooth growing front. The crystallization velocity slows markedly on cooling. Near room temperature a few nuclei form in the unsolidified melt and grow

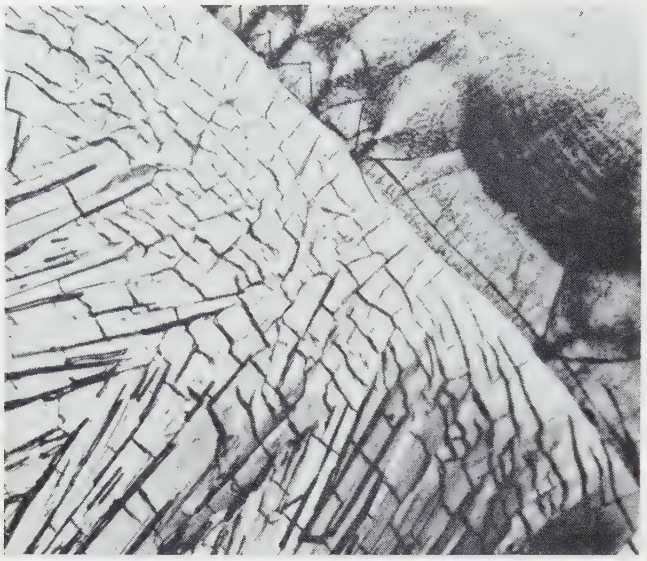

Fig. 13 Syringaresinol

Fig. 14 Syringaresinol diacetate

slowly as round spherules of radiating hairs, showing the extinction cross. The number of such nuclei increases greatly if the slide is warmed. The hair like crystals have parallel extinction, low to medium birefringence, and negative elongation, with the low index less than the melt, the high index greater than the melt.

In a meltback, narrow blades and threadlike crystals start to grow at a very rapid rate. These crystals twist and turn in all directions, leaving small pools of melt which rapidly solidify, creating a mass of solid of random orientation (Fig. 12). As the preparation cools, the crystallization velocity slows down, and most of the features described for the original solidification are repeated. The extent to which this very marked habit change is observed in the initial fusion depends on the extent of supercooling.

Repeated re-melting causes the eventual formation of a new, more stable polymorph. Platy crystals appear, which grow into well-defined rectangles. These join to form large areas of fairly uniform orientation (Fig. 12). A few air bubbles and fine shrinkage cracks appear. The crystals have parallel extinction, negative elongation, and high birefringence. At higher temperatures the stable polymorph grows at enormously smaller rates than the unstable form. The rate of polymorph transformation is nearly zero at room temperature.

Syringaresinol. The melt supercools to a glass. On warming and seeding, growth starts slowly, speeds up moderately with falling temperature, then again slows to nearly zero velocity at room temperature. Initially, crystals are blades of medium width with square ends. As growth proceeds, the crystals join to form fairly large areas of nearly uniform orientation. As the crystallization velocity decreases the crystal front becomes quite smooth in outline (Fig. 13). The last solid to form consists of aggregates of closely packed fine hairs of nearly uniform orientation.

The bladed crystals show high birefringence and approximately 45° extinction. One refractive index is less than the melt, the other is greater than the melt. The solid also shows a network of moderately coarse shrinkage cracks and long, narrow air bubbles (Fig. 13).

At room temperature, crystallization proceeds over a period of days as a fine grained granular mass, which frequently shows a distinctive pattern of ripple marks and shrinkage cracks (Fig. 13).

Syringaresinol Diacetate. The melt supercools to a glass. On warming and seeding, small squat rods grow at a very slow rate. As the temperature falls, the crystallization velocity slows to zero, and the crystal habit changes to a granular mass having a fairly smooth outline (Fig. 14). On repeated warmings, a few spontaneous nuclei may form. These grow in the same manner as described, but in the shape of spherules which show no extinction cross (Fig. 14). The rodlike crystals show relatively low birefringence, parallel extinction, negative elongation, and moderate contrast with the melt in all directions. A fairly prominent pattern of shrinkage cracks appears.

During the rewarming, other nuclei, consisting of feathery masses also appear in the melt. These grow into radiating, feathery tipped blades, which gradually coalesce to form spherules of fairly smooth outline (Fig. 14). This is probably an unstable polymorph. The crystallization velocity, although fairly slow, is very great compared to that of the previous polymorph. Another distinguishing factor is that all of the refractive indices of this unstable form are very close to that of the melt. The birefringence is apparently slightly greater for this form. The bladed crystals show parallel extinction and negative elongation. Spherules show the extinction cross although all extinction is rather diffuse due to crystal inperfections. Shrinkage cracks appear which are not quite so coarse and distinct as the cracks in the first polymorph.

CONCLUSIONS

From this study it is evident that the methods of identification by recognition, developed by what may be called the American group of microscopists, should be applicable in paper chemistry. The general types of behavior described by McCrone (*1*) are repeated here.

The advantage of these methods is obvious. For example, the dimethylethers of the two lirioresinols melt only a few degrees apart, and the parent compounds have identical infrared spectra (*2*). Nevertheless, it is possible to distinguish between these two compounds in less time than it takes to do a capillary melting point, if the present methods are used.

One difficulty does arise with these compounds. In fusion work, most compounds solidify rather rapidly, either at room temperature, or on warming over the alcohol flame. An unusually large percentage of the compounds studied here have abnormally low crystallization velocities. This causes no decrease in the simplicity of the method, or in certainty of identification, but only in rapidity. In this respect, lirioresinol *A* dimethyl ether and vanillin benzoate may represent the borderline of usefulness of the method. Experiments performed with sucrose, and with sucrose octaacetate, were not reported here because crystallization velocities were much slower than the two above mentioned compounds. An added result of this difficulty is the impossibility of determination of the relative stability of two solid forms, where they occur, in a reasonable time.

The trouble could probably be overcome, in part at least, by the inclusion of a Kofler hot bar as part of the necessary equipment. This would permit prolonged heating of the preparation at selected temperatures, impossible with the simple alcohol flame. Some increase in complexity and expense of equipment necessarily follows.

There is, however, a brighter aspect of the problems arising from slow crystallization velocities. With such compounds, the way should be open for quantitative measurement of crystallization rates, leading to even more positive identification, and also to quantitative estimations of purity.

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Received Nov. 6, 1959.

The author wishes to thank members of the staff of the Institute of Paper Chemistry for supplying the compounds used in this work.

Experience with Control Charts on Ink-Film Thickness and Sharpness

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Experience over a 12-month period with control charts on ink density and sharpness in lithographic printing is described. One of the experiments in color reproduction at the Rochester Institute of Technology calls for repeating results obtained using an offset press to print three colors on coated stock. Density and sharpness are measured with a densitometer. The pressman is asked to achieve a constant ink density and sharpness within one sheet and from sheet-to-sheet on all press runs. This paper describes how the pressman tries to achieve this uniformity and shows his results by means of control charts and related statistical tests. One batch of paper exhibited a periodic sheet-to-sheet variation. Paper tests were run on these sheets to see which of the test methods correlated with press results. Ink density correlated with basis weight, coating weight, gloss, brightness, and caliper.

The experience discussed in this paper was obtained from experiments in color reproduction at the Rochester Institute of Technology. In these researches effects of certain modifications, e.g., tone reproduction, of the process are studied to observe their effects on color reproduction. Gloss-coated paper is printed from presensitized negative plates on a 17 × 22 press with gloss inks. The press operation, platemaking, paper, ink, and ink film-thickness are controlled as well as possible so that the observed results are due to deliberately introduced effects rather than effects resulting from random variations in the printing operations.

Control is achieved by measuring the density of color bars printed on the sheet. The color bars consist of solids and 70% tints (Fig. 1). The cyan, magenta, and yellow color bars are measured using red, green, and blue filters in the light beam of the densitometer. These filters are selected because they produce maximum needle deflection. The press is adjusted at the beginning of the run to print a predetermined density on the solids of the color bar. The density of the solid is varied by adjustments made on fountain keys and ductor roller. The densities specified for the color bars were determined experimentally by printing three equal-dot-size halftones at ink densities which produced an approximately gray result. At the same time a density of approximately 1.6 was obtained in areas where the three solids overprint (*1*). Specification for dry ink densities were determined from these experiments to be: yellow 1.05, magenta 1.10, and cyan 1.35.

When these densities are achieved, the solids and 70% tints of the color bar are measured, and sharpness (fill-in) is computed. Sharpness as it is used in this

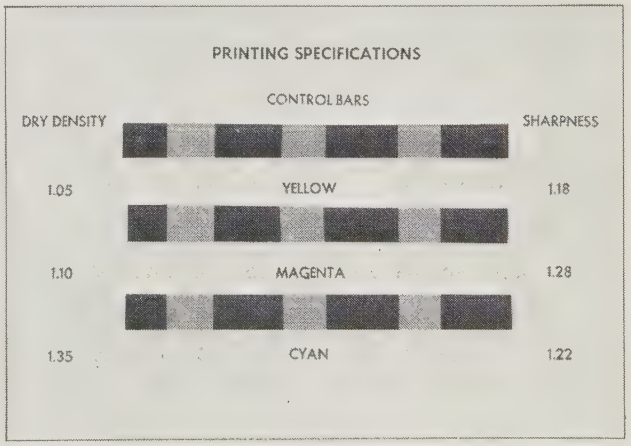

Fig. 1. Color bars, indicating the specifications for dry density and sharpness

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paper is the ratio of the solid density to the density of the adjacent 70% tint (*2*). This sharpness value is not manipulated.

The relationship between sharpness and press variables is extremely complex. Because of this, precise control of sharpness is impractical. Specification is based upon the average observed value over the

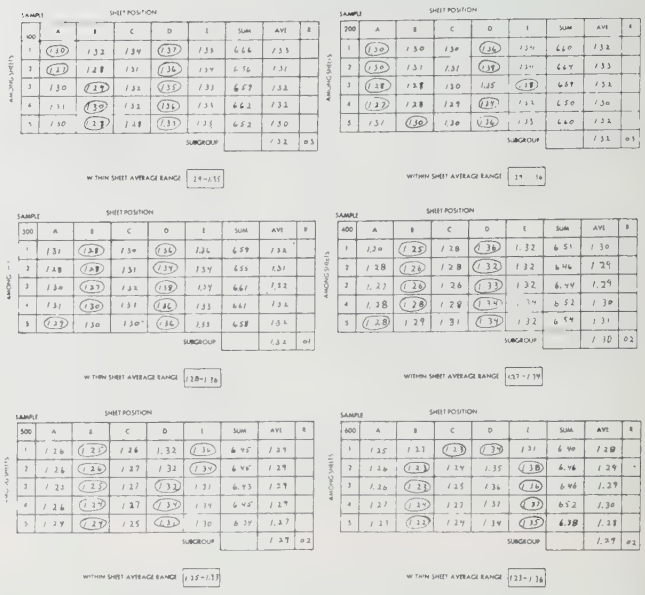
Fig. 2. The change in density with ink drying

The time is measured from the moment the sheet is printed. These curves are averages of several curves with a range of starting values.

experimental period. These values are yellow 1.18, magenta 1.28, and cyan 1.22. All values are based on reflection density measurements of dry prints.

Wet ink films immediately after printing do not measure the same as dry prints. Therefore, when adjusting the press and maintaining the density throughout the run, it is necessary to know the relationship between the wet density as measured immediately after printing and the resulting dry density some days later. Figure 2 shows how the average density changes with time after printing. From these curves it is evident that not all three inks dry down to the same degree. The wet densities of press sheets immediately after printing are specified at 1.30 for yellow, 1.30 for magenta, 1.57 for cyan with a tolerance of ±5% of the specified density.

It has been our experience that the press requires approximately 200 sheets to reach equilibrium after a

Table I. Data Sheet for "Postmortem" Control Charts on Dry Density

press adjustment has been made. Therefore, after each press adjustment, 200 sheets are run and the color bar rechecked before beginning the final run. After the press is adjusted to meet these specifications a run of 600 sheets is begun. During the run one sheet is pulled and measured every 50 impressions. After the final run has been completed, the sheets are set aside and allowed to dry for one day.

At this time five consecutive sheets are selected from every hundred printed. The color bars on these sheets are measured to obtain data for the "postmortem" control charts. Table I is an example of the data sheets of the dry density measurements made on the color bars. The sheet is measured in five locations across the cylinder, and there are five sheets in a sample (subgroup). The number of positions which

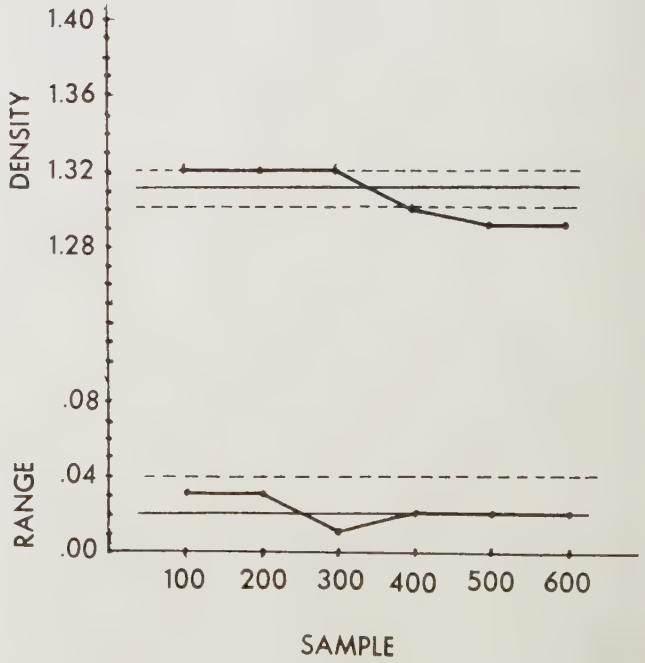


Fig. 3. Example of a control chart for one run of 600 sheets

are measured depends on the size and number of illustrations in the experimental plate. In some cases 10 or 15 locations across the cylinder may be selected for measurement.

The average sheet density is obtained as indicated in the right-hand column, Table I. The sample average and range are computed. These are plotted on a conventional variables control chart as indicated in Fig. 3. Upper and lower control limits for $\bar{X}$ chart are computed, $\bar{X} \pm A_2\bar{R}$. Control limits for the Range chart are $D_3\bar{R}$ and $D_4\bar{R}$ (3).

Occasionally it is desirable to show within-sheet variation on the control chart as well as variation among samples. This can be done from the data in Table I. In sample 100, sheet no. 1, the highest

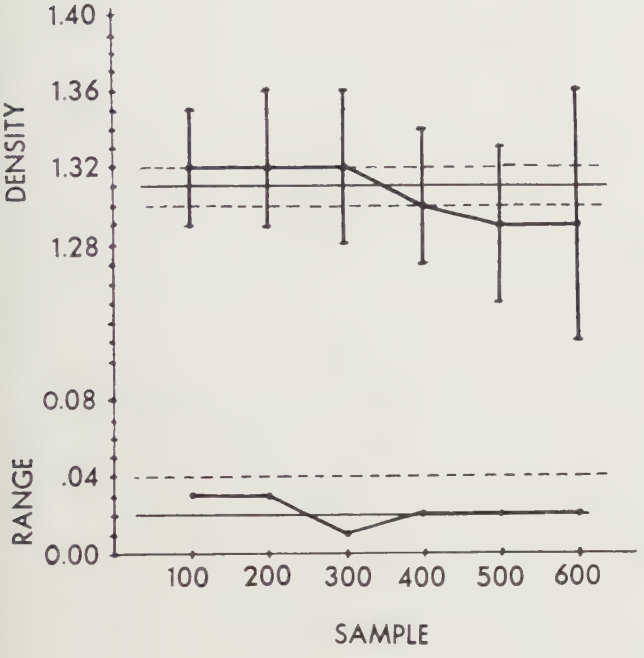


Fig. 4. Example of a control chart showing within-sheet variation as well as variation among samples

value, 1.37 (sheet position D), and lowest value, 1.30 (sheet position A), are circled. The difference, 0.07, represents the within-sheet range for sheet no. 1. For plotting, the average high sheet density, 1.35 for sample 100, and the average low sheet density, 1.29, is computed from the circled numbers. This is shown in the box labeled: "Within-sheet Average Range." The high and low values are transferred to the control chart (Fig. 4) in the same ordinate position (100) as in Fig. 3. The length of this line is an indication of the variation within individual sheets.

The resulting graph, Fig. 4, illustrates variation across the cylinder as well as variation from sheet to sheet and sample to sample. This type of control chart information is especially useful in such manufacturing operations as papermaking, web printing, sheet-fed printing, where the side-to-side difference is as serious as differences from sheet to sheet and from sample to sample.

Sharpness control charts are prepared in the same way from data, as illustrated in Table II. Densities

Table II. Data Sheet for "Postmortem" Control Charts on Sharpness

of solids and adjacent tints are recorded. The ratio of solid to tint is computed and recorded in the same box. This statistic is treated as described for Table I and Fig. 4. (All data required for Figs. 3, 4 and 5 are contained in Tables I and II.)

Since sharpness is not under the control of the operator, the within-sheet variation has a different meaning than within-sheet variation for density, which is controlled by adjustment of fountain keys. A significant change in within-sheet variation for sharpness must be interpreted to mean that an important change has occurred in the press or in materials. That we get any variation at all indicates that the press does not perform equally well at all cylinder

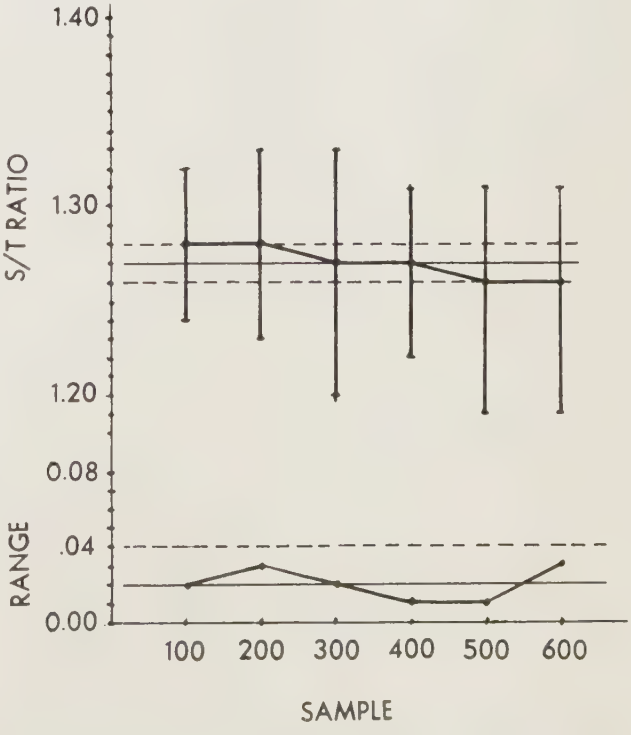


Fig. 5. Example of a control chart for sharpness (fill-in)

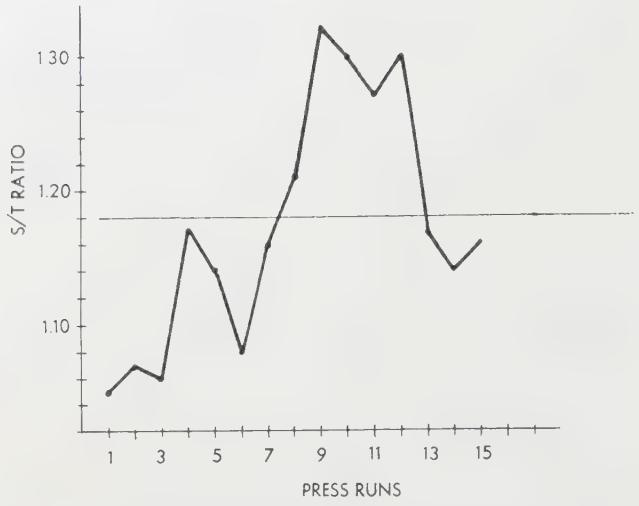


Fig. 6. Chart showing the uncontrolled variation in sharpness among runs (Yellow)

positions, or that the paper has a variation across the width. Examination of Table II shows that the outside edge of the press (position A) produced the lowest sharpness while the more central location (position C) printed the sharpest.

Figures 6, 7, and 8 show the average sharpness of one sample of five consecutive sheets taken from 15 press runs at intervals of approximately 2 weeks. This illustrates how the sharpness changed in uncontrolled and unpredictable ways from pressrun to pressrun. All charts show a significant increase in sharpness which began with the ninth pressrun and continued through run 12. This is an indication that some press or atmospheric condition resulted in unusually sharp printing during that period.

Figure 9 shows an accumulation of control charts for density over a period of 12 months. From this it can be seen that the sheet-fed printing operation at RIT is not in control, and that there are important time effects. Since the density of the print is entirely under the control of the operator (within the control limits) it is evident that the pressman did not hold the process to as small a variation as could be expected.

By observing these control charts, however, effects were found which would be difficult to find by any

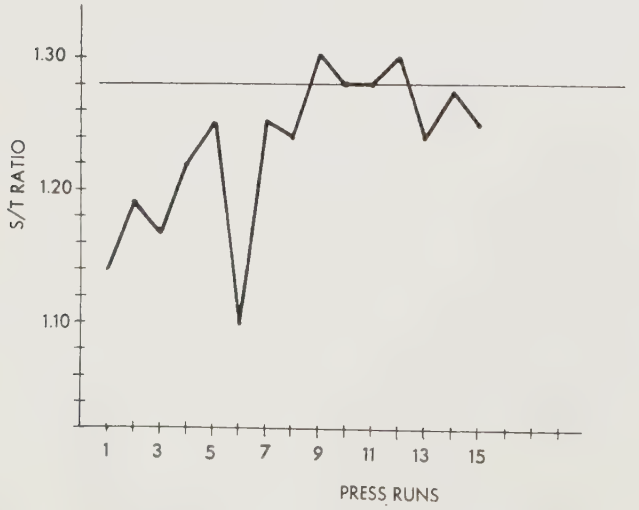


Fig. 7. Chart showing the uncontrolled variation in sharpness among runs (Magenta)

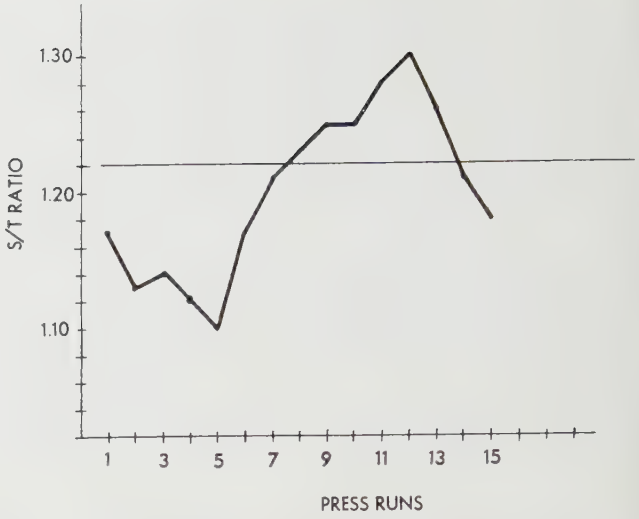


Fig. 8. Chart showing the uncontrolled variation in sharpness among runs (Cyan)

other means. For example, note the shift in the density level that occurred in pressrun A in Fig. 9. The magenta density suddenly tended to increase in a very consistent manner. The cause of this shift is not known. It coincided with a new batch of ink and could, therefore, be caused by a change in the dry-down characteristics. The dry density on most pressruns prior to this were below the 1.15 specified. The change, then, could be brought about by a shift in wet density aim point by the pressman.

Another effect was observed in the range chart for cyan at pressrun C in Fig. 9. Range charts are seldom out of control. Single out-of-control points in the range charts occur if the subgroup coincides with a press stop. The ink film thickness is high on the first few sheets at the beginning of a pressrun. If the subgroup contains some sheets before a stop and some after, then the range will be high. If the range is consistently high, as shown by C in Fig. 9, then some other reason must be sought.

Examination of the data from which the control charts were drawn, Table III, readily reveals the cause. Consecutive sheet values differ in a very systematic way. The values are low-high, low-high, low. From this we concluded that this lot of paper had been sheeted from two rolls with substantially different

Table III. Excerpt From a Data Sheet on Dry Density Showing the Systematic Consecutive Sheet Variation Caused by Paper Sheeted From Two Rolls

CONTROL CHART
DATA SHEET

SAMPLE — SHEET POSITION

AMONG SHEETS	100	A	B	C	D	E	SUM	AVE	R
	1	1.26	(1.24)	1.26	(1.28)	1.26	630	1.26	
	2	1.36	(1.32)	1.34	(1.38)	1.34	674	1.35	
	3	1.26	(1.24)	1.26	(1.28)	1.28	632	1.26	
	4	1.34	(1.34)	1.34	(1.38)	1.36	676	1.35	
	5	1.26	(1.24)	1.26	(1.30)	1.26	632	1.26	
						SUBGROUP		1.29	09

WITHIN SHEET AVERAGE RANGE (1.28 - 1.32)

Table IV. Results of Paper Tests and Density Measurements on Paper Sheeted from Two Rolls

Sample	*Basis wt.*	*Coating weight, %*	*Coating weight,*	*B + L gloss, %*	*Alinco brightness %*	*IGT pick, cm.*	*Gurley sec./25 cc. porosity min.*	*Minute oil absorption*	*Sheffield smoothness*	*Super micrometer, 2½ lb. pressure caliper*	*Reflection Densichron density of cyan solid*		*Transmission Macbeth density of cyan solid*
26	77.6	...	...	74	78.5	...	528	...	9	0.00470	1.32	Low	1.22
27	74.1	14.7	10.89	77	80.5	...	414	...	17	0.00485	1.36	High	1.24
28	76.7	16.0	12.27	73	79.7	...	500	...	17	0.00470	1.32	Low	1.24
29	74.0	14.8	10.97	80	80.5	...	530	...	15	0.00485	1.37	High	1.23
30	77.2	17.7	13.65	74	79.7	...	450	...	15	0.00470	1.32	Low	1.20
31	75.0	14.8	11.10	80	80.7	...	533	...	..	0.00485	1.39	High	1.25
32	76.7	16.0	12.27	73	79.8	5	405	14.0	13	0.00470	1.30	Low	1.18
33	74.3	...	...	80	80.8	...	411	12.5	12	0.00485	1.35	High	1.20
34	76.3	...	...	73	79.7	4.5	513	11.0	11	0.00470	1.28	Low	1.20
35	74.3	...	...	79	80.7	4.5	532	14.5	13	0.00485	1.36	High	1.25
36	76.8	...	...	73	79.8	5.5	340	10.5	12	0.00470	1.30	Low	1.17
37	74.9	15.3	11.45	80	80.6	...	500	...	18	0.00485	1.36	High	1.23
38	76.8	15.7	12.00	73	80.0	...	400	...	12	0.00470	1.34	Low	1.19
39	74.1	...	...	80	80.7	...	500	10.0	15	0.00485	1.38	High	1.24
40	76.6	...	...	73	79.7	4.5	445	14.0	10	0.00470	1.31	Low	1.17
41	75.2	14.9	11.20	78	80.7	5.5	400	12.5	9	0.00485	1.36	High	1.23
42	77.1	16.2	12.49	75	79.7	...	510	...	12	0.00470	1.310	Low	1.18
43	79.5	...	...	79	80.9	3.5	355	11.0	13	0.00485	1.312	High	1.20
44	76.1	...	...	74	79.9	...	...	15.0	15	0.00470	1.32	Low	1.18
45	74.1	15.0	11.11	80	80.8	...	530	10.0	11	0.00485	1.37	High	1.26
46	76.6	16.0	12.25	74	79.7	6.0	...	...	10	0.00470	1.28	Low	1.16
47	73.9	15.7	11.60	78	80.6	...	...	14.0	10	0.00485	1.38	High	1.20
48	76.8	15.9	12.21	73	79.7	...	205	...	12	0.00470	1.30	Low	1.13
49	74.5	...	...	78	80.3	...	330	15.0	12	0.00485	1.31	High	1.15
50	77.5	...	...	73	79.8	...	505	16.0	12	0.00470	1.28	Low	1.14
51	74.1	...	...	79	80.2	...	...	15.15	13	0.00485	1.33	High	1.17
52	77.7	...	...	73	79.2	...	430	11.0	9	0.00470	1.30	Low	1.15
53	74.6	...	...	80	80.4	3.5	500	16.0	13	0.00485	1.36	High	1.19
54	77.5	...	...	73	79.4	4.5	401	12.5	11	0.00470	1.27	Low	1.12
55	77.4	...	...	76	78.6	...	401	...	12	0.00485	1.34	High	1.15

printing characteristics. We had found a significant difference between papers from a single manufacturing process.

Ordinarily, when two papers are nearly alike, it is difficult to distinguish between differences in printing conditions and those in papers. Since these effects were found in consecutive sheets differences must have arisen from paper effects rather than press variables.

Samples of paper were tested to find out which tests correlate with ink film thickness. Basis weight, coating weight, gloss, brightness, and caliper were all found to correlate well with reflection density of solid prints. The difference in observed density might have been caused by gloss and brightness differences of the two papers. To test this and to determine if more ink was transferred, the transmission density of solids was measured (*4*). The last column, Table IV, is a compilation of these data. It is obvious that prints with higher reflection density do in fact have more ink on them.

Some characteristic of this paper did have a significant effect on the transfer of ink. Since the sheet with greater coating thickness has less gloss and lower brightness, it is likely that differences in coating composition is the principal contributing factor.

The use of control charts on ink film thickness and sharpness have begun to yield information about lithographic printing which, because of the variability of the process, cannot be obtained any other way. Through analysis of these "postmortem" charts and systematic record keeping, it may be possible to isolate effects of press conditions, press operations, plates, ink, and paper. The studies of printing characteristics which are applicable to existing printing methods must be made by means of control charts such as those described in this paper combined with some of the more powerful statistical tools.

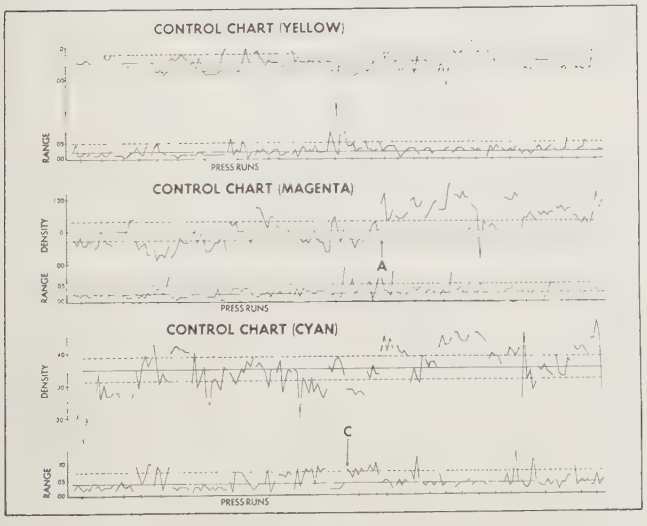


Fig. 9. Cumulative record of control charts covering 28 pressruns over a period of 12 months

"A" indicates the position in the series where the magenta density increased. "C" indicates a pressrun in which paper sheeted from two rolls was used.

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The Interaction of Processing Variables, Base Materials, and Resins in Polyethylene Extrusion Coating

J. P. GOSLIN and H. F. SWEENEY

Many processors in the extrusion coating industry use one or two base materials and a single resin. With broadening markets, there is a concurrent demand for wider product selection. Coaters are becoming familiar with a greater variety of substrates and resins, and more detailed performance information would be helpful in using these materials. This paper describes the effects of processing variables on the adhesion and heat seal properties of six polyethylene resins coated to each of five base materials: kraft paper, MSAD-80 and "K" type cellophane, Mylar® and aluminum foil. Resins of widely different melt index and density illustrate how these parameters influence finished product quality. The processing variables studied include melt temperature and gage. Their effects on adhesion and their variations among resins and substrates are described. Heat sealing strength trends demonstrate the important role of the base material, and the complex relationships of variables.

THE universal concern of processors in the polyethylene extrusion coating industry is to obtain good adhesion and heat seal strength in the coatings they make. Our purpose is to examine the effect of processing variables on adhesion and heat sealing characteristics for several polyethylene resins and base materials. One important effect we will examine is how the temperature-viscosity relationship of each resin affects adhesion, and how knowledge of this relationship can aid in selecting a melt temperature for production. In interpreting heat-seal properties of a coating, the question frequently arises, "What are the respective roles of the resin and the base sheet?" This question is answered in the following discussion.

BASE MATERIALS

The base materials in this study include 40-lb. kraft paper, Mylar® "K" 202† and MSAD-80 cellophane,‡ and aluminum foil. The particular kraft chosen had a tight fiber formation, similar to grades used in commercial polyethylene coating. "K" 202 cellophane is typical of the "K" films used for packaging bakery products, cheese, and candy. The base cellophane has a polymer coating on each side for moistureproofness. Other "K" type cellophanes differ from "K" 202 in yield or slight surface modifications. In this discussion we will refer to "K" 202 as " 'K' type" since it is representative of the family. However, adhesion differences among the "K" films could be expected because of variations in wettability. This cellophane was 450 gage, equal to 1.4 mils in thickness.

MSAD-80 cellophane is specifically designed for packaging of fresh meat in supermarkets. It has an anchored moistureproof coating on one side and is water wettable on the other. This latter surface is wettable so that meat juices can cling to the film and form a seal without an intervening air layer between the film and the meat. Polyethylene is coated on the water wettable surface for increased heat sealability, leakage protection, and durability. Like "K" 202, MSAD-80 cellophane is representative of films having the same characteristics, and in the following discussion will be called MSAD-type; 450 gage or 1.4 mils was used, the same as for "K" type cellophane.

Type A Mylar® polyester film was the fourth substrate coated. It is the conventional variety of this tough, transparent polyester film, without special surface modifications. Interest in polyethylene coated Mylar® has received impetus from recent activity in skin packaging and boilable pouches. The gage was 100, equivalent to 1 mil. The aluminum foil used was fully annealed, dead soft, in a 1 mil thickness.

Processors who coat cellophane, Mylar®, and foil are aware that these base sheets as received do not have surfaces receptive to good adhesion. Primers or adhesion promoters were applied to the "K" type cellophane, Mylar®, and foil as commonly done in commercial practice to obtain adhesion. The specific primers will be discussed in the section on adhesion for these base materials. MSAD-type cellophane was not primed because earlier experiments indicated no significant adhesion improvement from priming.§

POLYETHYLENE COATING RESINS

The Alathon‖ polyethylene resins used for coating in this study were selected for their ability to attain adequate adhesion and heat seal strength, and because they represent ranges in melt index and density which are typical of resins extruded in the industry. Table I lists the six resins; all are conventional branched polyethylenes, without additives except for antioxidants. Resins "U," "Z," and "W" are all in the low density range of 0.915 to 0.918, but vary in melt index from low to very high, or 3.4, 10.0, and 23.0, respectively. At 0.930, Resin "X" is an intermediate density, branched resin near the upper end of the density range for present commercial branched polyethylenes; this resin contains no antioxidant. Midway are "V" and "Y" at a density of 0.923, but with melt indices

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‡ Mylar®, "K" 202 cellophane and MSAD-80 cellophane are manufactured by the Film Department of E. I. du Pont de Nemours & Co. Inc.

§ H. C. Barker, *et al.*, *Paper, Film and Foil Converter*, May and June, 1958.

‖ Alathon® is the registered trademark for polyethylene resin produced by the Polychemicals Department, E. I. du Pont de Nemours & Co., Inc.

Table I. Alathon® Polyethylene Resins

Resin	Density, g./cc.	Melt index
"U"	0.917	3.4
"V"	0.923	3.1
"W"	0.915	23.0
"X"	0.930	3.0
"Y"	0.923	8.0
"Z"	0.918	10.0

of 3.1 and 8.0, respectively. In interpreting resin influences on the quality of coatings, it will be possible to make comparisons by holding either density or melt index as a constant. For example, at a melt index of about 3.0, there are densities at 0.917, 0.923, and 0.930.

EXTRUSION COATING EQUIPMENT

In attempting to translate data obtained in a laboratory to information for use in daily production, the important variable of scale-up from small to large equipment frequently is a barrier which clouds the value of the laboratory data. If, in a particular case, thin high-speed coatings are an important production consideration, they should actually be run. Results from a small, low-output extruder at greatly reduced speeds and thicker weights cannot be predicted upward with sufficient accuracy to make them reliable. This difficulty was overcome by using a $4^1/_2$ in. Hartig extruder having a 21:1 length to diameter ratio and capable of an output of 400 lb. per hr., together with an Egan extrusion coater having a maximum linear rate of about 1000 f.p.m. The extruder screw was a metering type with a 4:1 compression ratio, having a rapid transition over a half-turn from the conveying to the metering section. The die used was a 30-in. Egan, center-fed, of the familiar T-type. This design has a cylindrical manifold $1^1/_2$ in. diam., and the body is fitted with extended die lips, in this case set at 20 mils. In lieu of rods or internal blocking, positive deckle blocks were mounted across the face of the die lips, positioned for a die slit width of 24 in.

Melt temperatures were measured by inserting melt thermocouples in the adaptor between the extruder and die and in the die manifold, so that the thermocouples projected $^1/_2$ in. into the melt stream. Heating zones on the extruder and die could then be adjusted to equalize melt temperature in all locations.

PROCEDURE AND TESTING

Examination of any group of variables involves the selection of ranges for investigation and decisions on which factors should be held constant. In this study all coatings were made at a $2^3/_4$-in. air gap and at an output of 150 lb. per hr. Screw speed was changed as necessary to maintain this rate for the various resins and for goal melt temperature points with specific resins. While the output was below maximum for the extruder, it was high in terms of linear speeds for a narrow web. Drawdown tests indicated that takeoff rate rather than output was a limitation, since several resins drew to 0.2 mil without weaving or tearing at 1025 f.p.m., but could not be drawn thinner because the maximum takeoff rate had been reached.

Each of the six resins was coated onto all five base sheets at melt temperatures of 550, 575, 600, and 625°F. One- and two-mil coatings were made at the first three temperatures and $^1/_2$-mil gages at the last three points. Average coating speeds were 110, 215, and 440 f.p.m. at thicknesses of 2, 1, and $^1/_2$ mil, respectively. The speed and thickness range could not be covered for all resins. At 625°F., viscosity was too low for practical operation in the high-melt index polymers. Drawability at low temperatures prevented high-speed thin coatings in one of the resins. While air gap is an important variable, it was held constant except for neck-in measurements because of the large mass of data already involved. Neck-in and drawdown were measured for all resins throughout the temperature and speed ranges.

Adhesion on all base materials except kraft was measured by peeling samples on an Instron tensile tester. Adhesion on kraft was tested on a Perkins-Southwick bond tester, to be discussed in the section on kraft adhesion. Values from the Instron test are averages of five peels for a sample extruded at a given set of conditions. Strips 1-in. wide were peeled apart at a jaw separation speed of 12 in. per. min. Results are expressed as grams per inch of web width, representing an average of the peak force necessary for peeling.

Heat-seal specimens for all substrates were prepared on a Model 12 Sentinel heat sealer, having a 1-in. wide jaw heated only on one side. Conditions for sealing were a $^1/_2$ sec. dwell time at a jaw pressure of 40 p.s.i.; temperature was increased from 250 to 450°F. in 25° increments. At each sealing temperature, five specimens were peeled on the Instron in the same manner as for adhesion. Results were also averaged in grams per inch of web width.

ADHESION ON KRAFT PAPER

Kraft paper is the largest volume base material in the extrusion coating field. Therefore, serious consideration must be given to the ability of a resin to bond to kraft paper. Adhesion to kraft is based primarily on the surface structure of the paper and on the capacity of the polyethylene to mechanically bond to this surface. The fibrous surface and the open formation of the paper promotes the mechanical penetration of polyethylene under temperature and pressure. In addition to the paper surface characteristics, the degree of penetration or mechanical bonding will also be affected by the temperature-viscosity relationship of the resin. While these two influences dominate the adhesion characteristics for most types of paper, their effects are modified significantly by fiber formations, calendering, surface finishes, and chemical additives.

The adhesion values to follow were calculated as "per cent adhesion" from results of tests on a Perkins Southwick bond tester.¶ In this dynamic test, the objective is to attempt bursting by air pressure both through the polyethylene coated side and through the uncoated paper surface. Tests through the coated side are the reference, since they remain relatively constant, while those through the uncoated side serve as the variable, based on degree of bonding.

Figure 1 shows the per cent adhesion on kraft for all resins at a 600°F. melt temperature, and compares three separate coating weights. In this graph the general

¶ Described in a paper by C. P. MacDermott and J. E. Guillotte, of E. I. du Pont de Nemours & Co., Inc., presented at the 11th Annual Plastics-Paper Conference of TAPPI, Appleton, Wis., Oct. 3, 1956.

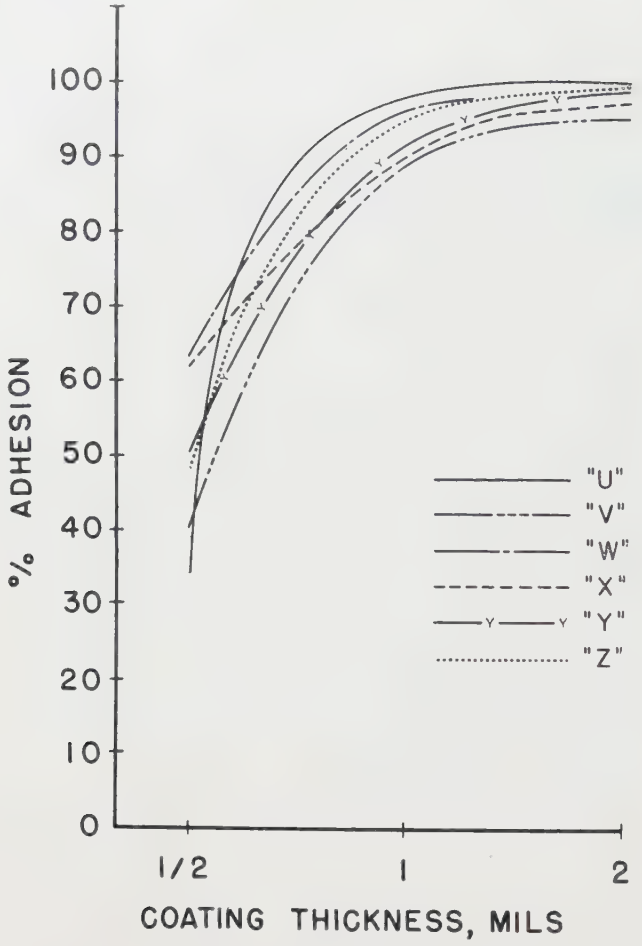

Fig. 1. Per cent adhesion on kraft
600°F.—All resins

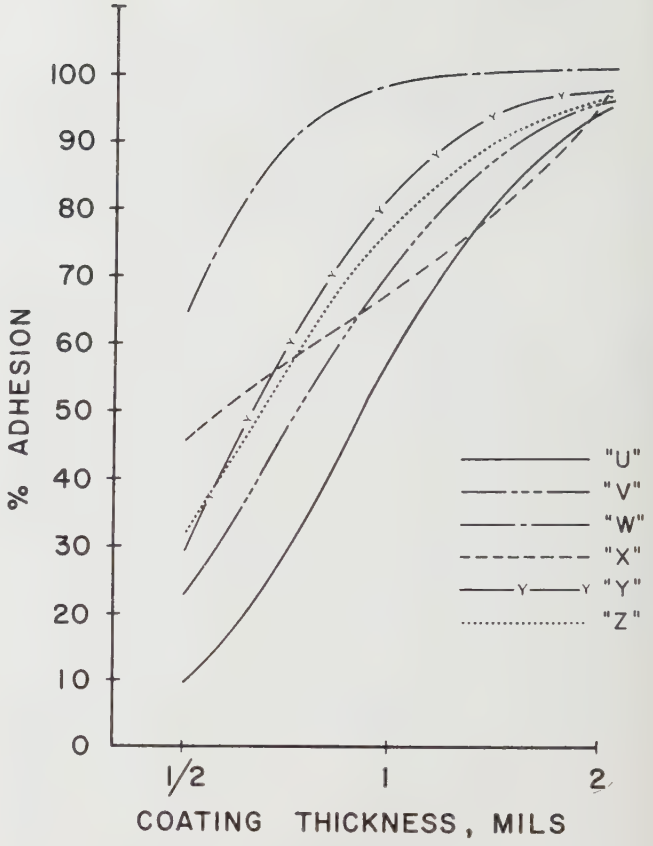

Fig. 2. Per cent adhesion on kraft
575°F.—All resins

level of adhesion is dependent on coating thickness, with 1- and 2-mil coatings having excellent adhesion, but with $^1/_2$-mil gages being in the borderline range. There are only minor differences in adhesion among the resins at the heavier weights, but the greater disparity at $^1/_2$ mil reflects the fact that the less viscous high melt-index resins have greater penetrating ability. Differences tend to equalize for heavier coatings because for all resins, there is more heat retention in a thick molten web than in a thin one. Stated differently, the degree of adhesion depends on the temperature of the melt as it contacts the base material. In this example a thicker coating retains more heat during travel of the web in the air gap, so that there is greater melt fluidity in the extrusion nip and, consequently, better penetration into the paper surface.

Since melt temperature and fluidity at the instant of contact between the paper and polyethylene determine adhesion, the extruder must deliver polymer exiting the die which is sufficiently hot for obtaining adhesion at a given set of extrusion conditions. To date there has been no empirical formula developed which can predict the loss of heat in the air gap, and there is no precise method for measuring melt temperature at the nip. Without such tools, processors must rely on experience with their equipment and their knowledge of resins in selecting the melt temperature. The choice is especially important in thin coatings, where heat loss in the air gap is more rapid. Figure 2 illustrates that at a melt temperature of 575°F., 2-mil coatings have good adhesion at only a slightly lower level than for a 600°F. melt temperature. However, for the $^1/_2$ and 1-mil gages, the resin curves are more divergent than in the previous diagram. Considering 60% as the minimum point for adequate adhesion, all resins except "W" have poor adhesion at $^1/_2$ mil. As observed previously, this is because the very high melt index promotes low viscosity, even at reduced melt temperatures. Even at the 1 mil coating weight, adhesion for the lower melt index resins "U," "V," and "X" is barely adequate because of the temperature-viscosity relationship.

The expected improvement in adhesion when melt temperature is raised can be noted in Fig. 3, a comparison of the adhesion on kraft for 1-mil coatings. All resins demonstrate good adhesion in the 600–625°F. melt-temperature range. Resin "U," having the lowest density, shows a sharper rise than the others, but reaches a higher final value at 600°F. Resin "W" levels off between 575 and 600°F., indicating that 575°F. would be a better operating point because there would be less neck-in at the lower temperature, and no adhesion gain in going higher.

For thin coatings extruded at high speeds, the necessity of choosing the correct melt temperature is demonstrated by curves for $^1/_2$-mil coatings in Fig. 4. In the previous diagram (Fig. 3) for 1-mil gages, adequate adhesion could be obtained at 600°F.; but the optimum point advances to 625°F. for the $^1/_2$-mil thickness, since only two resins have passable adhesion at 600°F. Close nesting of the curves at 625°F. indicates that viscosity differences are minimized at high temperatures, which was observed previously for thick coatings but at lower temperatures. An interesting melt-index effect is shown in the curves for resins "V"

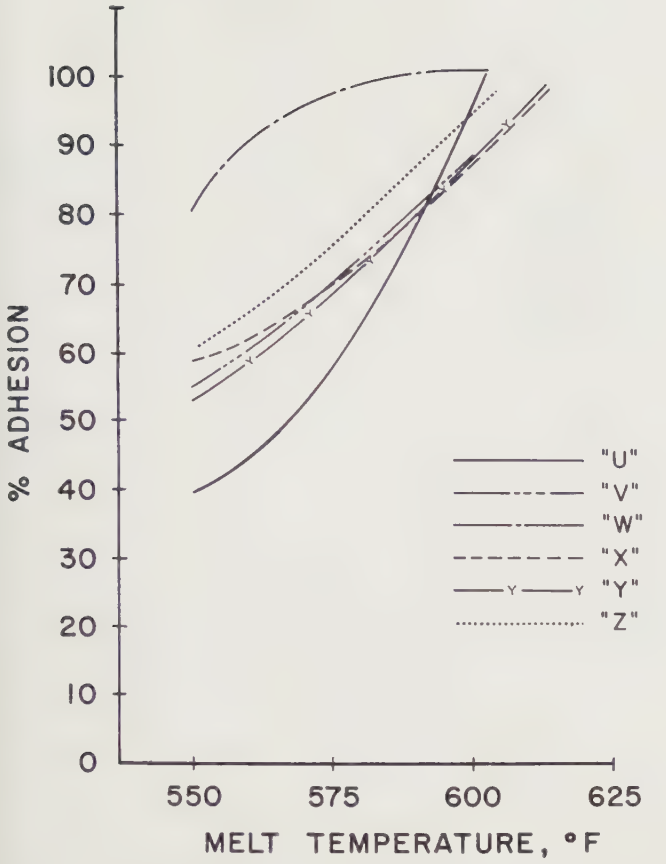

Fig. 3. Per cent adhesion on kraft
1 mil—All resins

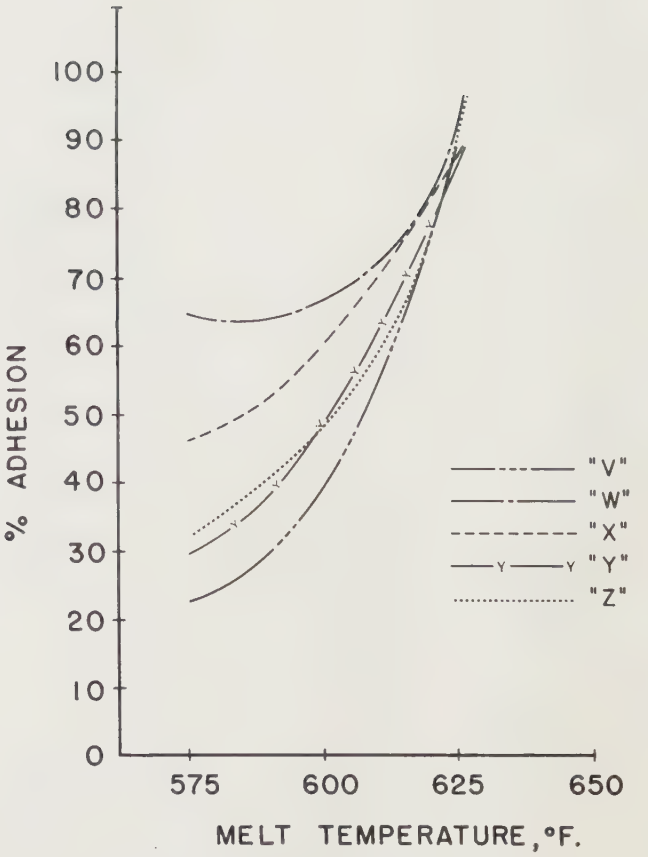

Fig. 4. Per cent adhesion on kraft
1/2 mil—Resins "V," "W," "X," "Y," "Z"

and "Y," which have the same density. The rise in adhesion is almost parallel, with "Y" at a slightly higher level because of reduced viscosity at all temperatures.

When melt temperature versus adhesion is plotted for a single resin at three thicknesses as in Fig. 5, the significant point is that good adhesion is possible throughout a broad operating range for a 2-mil coating, but the range becomes progressively narrow at thinner weights. This was true for all resins except "W," and resin "X" is used here only to illustrate the point.

FACTORS AFFECTING ADHESION

In addition to coating thickness and melt temperature, two other important factors which affect adhesion are the air-gap length and the web speed. The adhesion and heat seal data discussed here are for coatings at a $2^{3}/_{4}$-in. air gap, the minimum which could be set because of equipment limitations, i.e., the clearance necessary between the die and cooling drum. On other equipment, where shorter air gaps might be possible, there would be more heat retention in the web at equivalent coating speeds and weights. Therefore, the temperature required for adequate adhesion would be lower. Conversely, higher melt temperatures would be needed for kraft adhesion at longer air gaps.

Usually, an increase in web speed reduces adhesion, if other variables are unchanged. Since our runs were made at a constant output of 150 lb. per hr., coating weights were adjusted by changing the linear rate. For gages of $^{1}/_{2}$, 1, and 2 mils, average speeds were 440, 215, and 110 f.p.m., respectively. If, on another coater, variables such as melt temperature and air gap were the same as in our experiments but with a major difference in coating speeds for the same temperature and thickness, adhesion could be expected to change. Accordingly, in interpreting adhesion and heat seal data, the term "optimum melt temperature," as used here or elsewhere in extrusion coating studies, must be modified by relating particular figures to differences in equipment and operating variables.

In obtaining adhesion on base materials other than kraft, variables such as coating thickness, melt temperature, air-gap length, and web speed again influence adhesion, and for the same reasons as in kraft. But unlike the fibrous lattice of the kraft surface, we find smooth finishes on cellophane, Mylar® and foil; surfaces which are not likely to bond mechanically to polyethylene. This characteristic also applies to many papers, where there is a smooth, hard surface or a close fiber formation. On such surfaces there is a combination of mechanical and chemical adhesion.

As in kraft, the coating of smooth base stocks must be done at high enough temperatures to maintain fluidity or give the polyethylene a wetting action. But if the bonding cannot be mechanical it must be chemical, and this poses a problem because the polyethylene surface is inert and almost nonpolar. The two common methods of obtaining a chemical bond are: (1) coating the base material with a highly polar adhesion promoter or primer, to act as an interface between the low-polar substrate and nonpolar polyethylene; and (2) the formation of polar groups by oxidizing the polyethylene surface itself. This is accomplished by lengthening the air gap, which significantly increases the amount of oxidation occurring in the usual short air-gap distance.

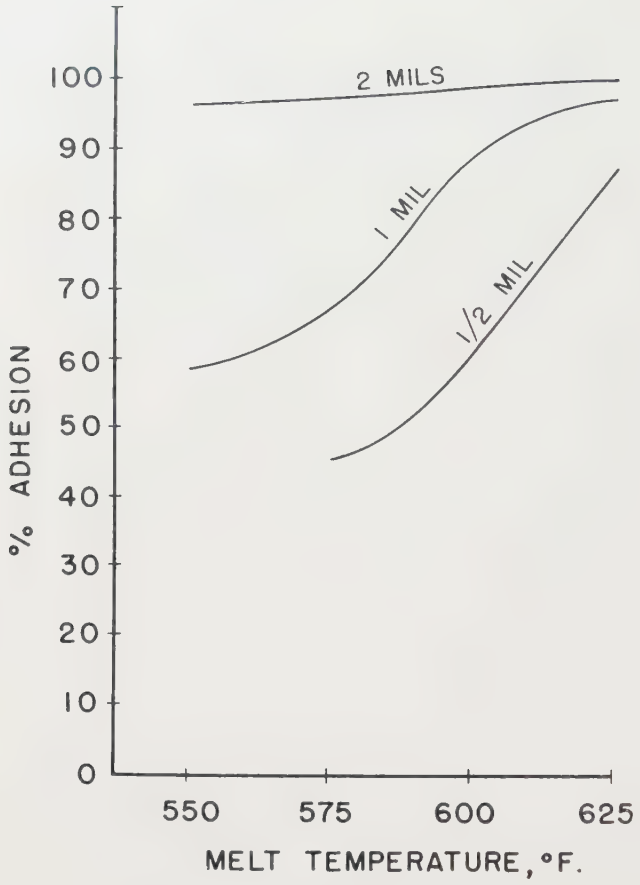

Fig. 5. Per cent adhesion on kraft
1/2, 1, and 2 mils—Resin "X"

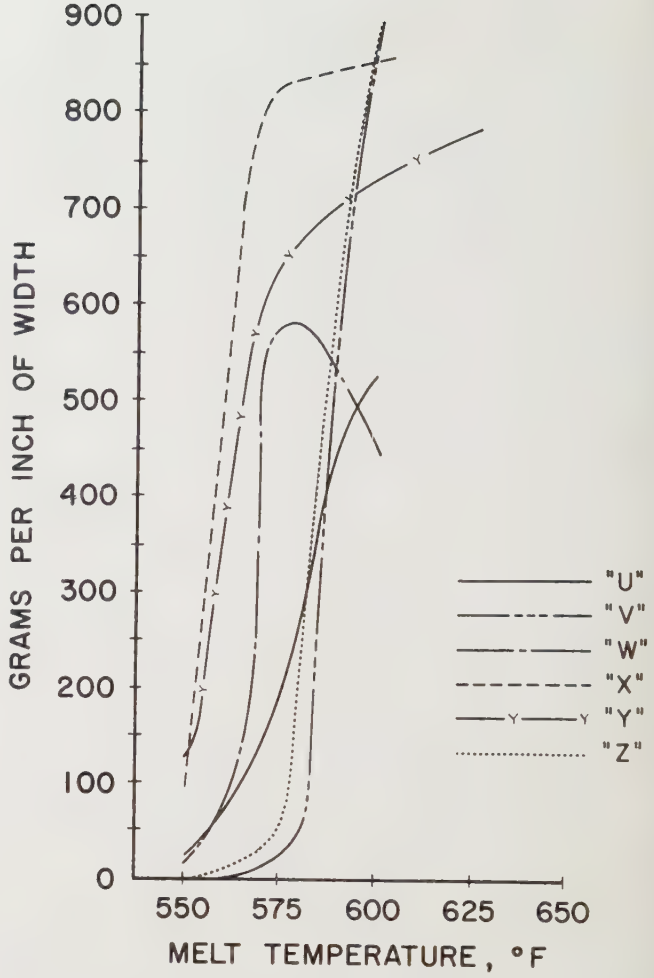

Fig. 6. Adhesion on foil
1 mil—All resins

There are several problems if longer air gap is chosen rather than primers as a method of gaining adhesion.

1. Melt temperature must be raised to compensate for the additional heat loss in a longer air gap. This makes gage control and web handling more difficult. There is greater tendency for the web to weave and to flutter from stray air currents. Adhesion and heat seal strength values are more erratic when extremely high temperatures are employed at long air gaps.

2. Increases in air gap length and melt temperature cause the web to neck-in more, with are sultant higher scrap loss.

3. Greater oxidation occurs not only on the polyethylene surface which contacts the base stock, but also on the reverse side. This can result in the formation of unpleasant odors. In addition, there is a reduction in heat seal strength because of oxidation, and the sealing temperature required to obtain good seal strength is higher. This narrows the range for adequate sealing, and may slow down the cycle time on automatic sealing equipment. Attempts to overcome these problems by using a nitrogen blanket on the chill-roll side of the polyethylene web presents a further difficulty. The nitrogen must be maintained on one side of the web only, excluding the gas blanket from the polyethylene surface which contacts the base material, so that oxidation can perform its adhesion-promoting function. Also, unless nitrogen is bled into the nip at a high enough temperature, the gas tends to cool the polyethylene web and reduce its wetting ability.

For these reasons, and because new and more effective primers have gained wider industry acceptance for the priming technique, it was investigated in this study rather than the oxidation technique. The specific primers used were Tyzor* AP(TPST) and Tyzor AA (Titanium acetylacetonate). Tyzor AP (TPST) is a mixed isopropyl-stearyl titanate ester, in this case about a 5% solution in heptane. It was used to prime "K" type cellophane, and was selected because of its ability to wet the polymer surface of this particular cellophane. Tyzor AA was used as an approximately 5% solution of titanium acetyl acetonate in a 50% mixture of isopropyl alcohol and water, to which was added 0.5% acetic acid. Tyzor AA was primed on Mylar® and aluminum foil, and was selected because of its ability to wet these surfaces uniformly and because of the good stability of this primer in solution. It does not effectively wet the polymer coating on "K" type cellophane, however, so Tyzor AP was selected.

There are several manufacturers who produce adhesion promoters for extrusion coating. Since the choice of a primer for a particular substrate significantly affects adhesion results, the selection is an area which requires careful investigation by the fabricator. In this case, our selection is not necessarily a recommendation that optimum results can be achieved with the primers used, but reflects our experience in using them and availability of the application equipment.

* Tyzor is a trademark of E. I. du Pont de Nemours & Co., Inc., for organic titanates manufactured by their Organic Chemicals Department.

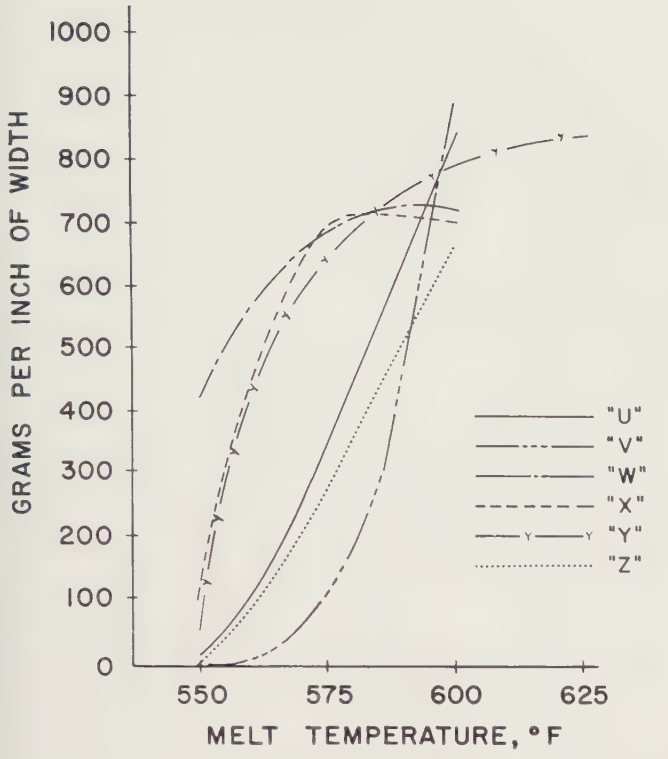

Fig. 7. Adhesion on Mylar®
1 mil—All resins

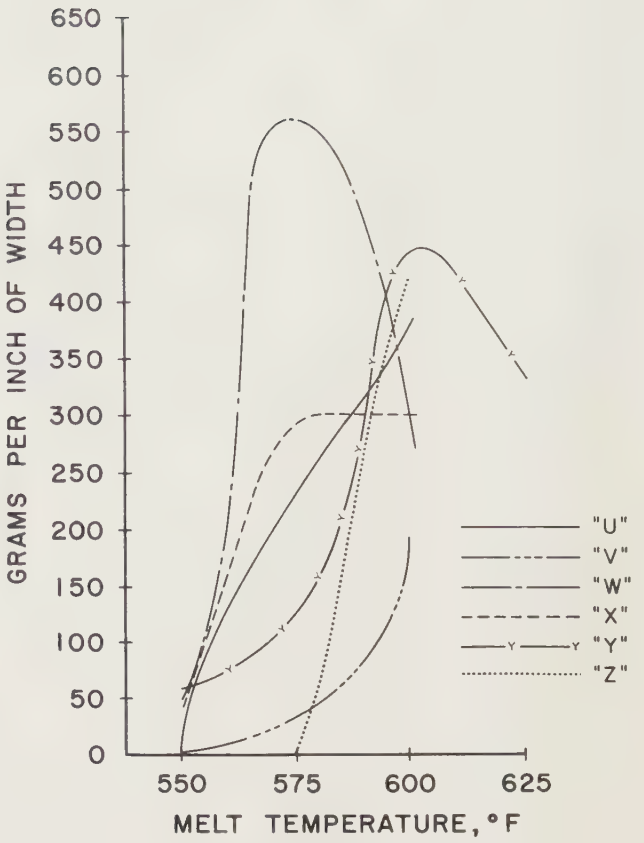

Fig. 8. Adhesion on cellophane ("K"-type)
1 mil—All resins

Both primers were coated on the base materials in a commercial printing plant by using a flexographic press.†† An excess solution was applied in a solution trough and then removed by a doctor bar until only a very thin layer remained. After passing the primed substrate through an air drying oven, the rolls were rewound and stored. To simulate commercial operations and maintain laboratory control, there was a storage time of four to six weeks between the priming and the polyethylene coating operations.

In general, adhesion values for each base material followed trends which could be predicted from polyethylene resin properties and extrusion conditions. However, significant differences in levels of adhesion were noted among the substrates. Adhesion to Mylar® and foil was greater than adhesion to kraft paper, and kraft exhibited higher adhesion values than "K" type or MSAD-type cellophane.

Adhesion on Smooth Surfaces

Figure 6 is a comparison of the adhesion characteristics of all resins on aluminum foil. A direct comparison cannot be made between ultimate adhesion values in kraft paper and foil because the testing methods and scales of measurement differ. Kraft adhesion is measured in per cent, while values for the other base stocks are given as grams of adhesion per inch of coated width. However, the difference in shape of the curves for foil and kraft indicates that the rise in adhesion from increasing the melt temperature is much sharper for foil. This trend is consistent in each of the resins tested, and is due primarily to the sensitivity of foil adhesion to oxidation. The significance is that for several resins, 1-mil foil coatings have excellent adhesion at 575°F., a relatively low melt temperature. An advantage of a low coating temperature is that it would tend to minimize odor formation.

All resins show adequate adhesion in the 575 to 600°F. melt-temperature range, with peak values as high as 895 g. As observed for adhesion on kraft, these values would be affected by changes in processing conditions. For example, in this case an air gap longer than the $2^{3}/_{4}$ in. used would allow peak values to be reached at temperatures lower than shown, because of increased oxidation.

In Fig. 7, a comparison of adhesion for all resins at 1 mil on Mylar®, there is the same general pattern as observed in foil adhesion. The rise in adhesion with increasing melt temperature is less than in foil. However, peak values are in the same range, above 700 g. The peak point for resin "V" is higher than for the other resins, and the particular value of 900 g. is almost identical for the two substrates. While adhesion on Mylar® is good for all resins and maximum

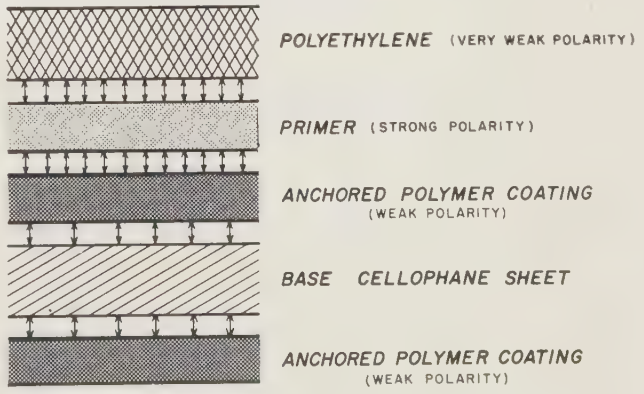

Fig. 8A. Cross section of polyethylene coated on primed "K" type cellophane

†† Diaphane Corp., Philadelphia, Pa.

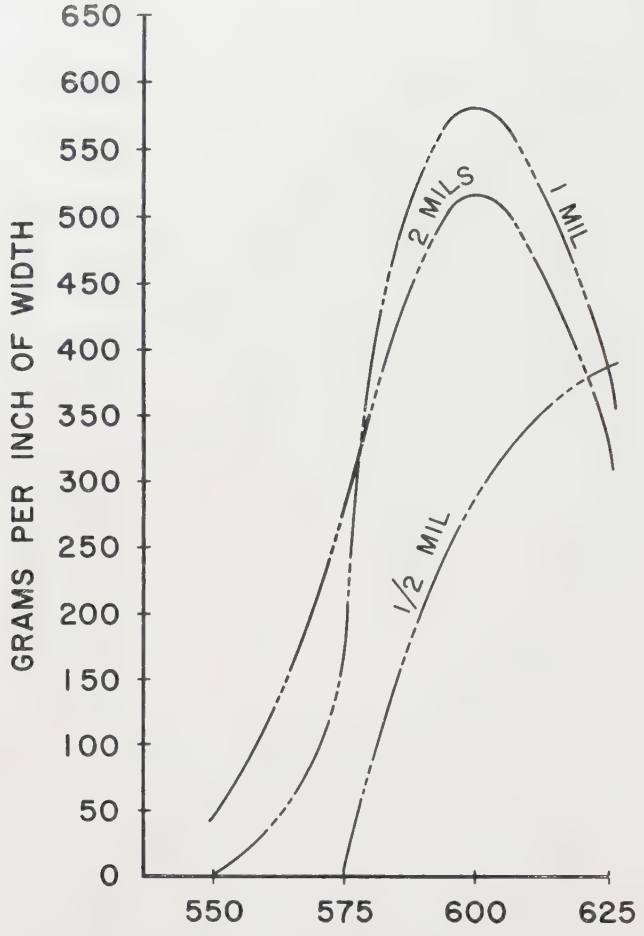

Fig. 9. Adhesion on cellophane (MSAD-type)
1/2, 1, and 2 mils—Resin "Y"

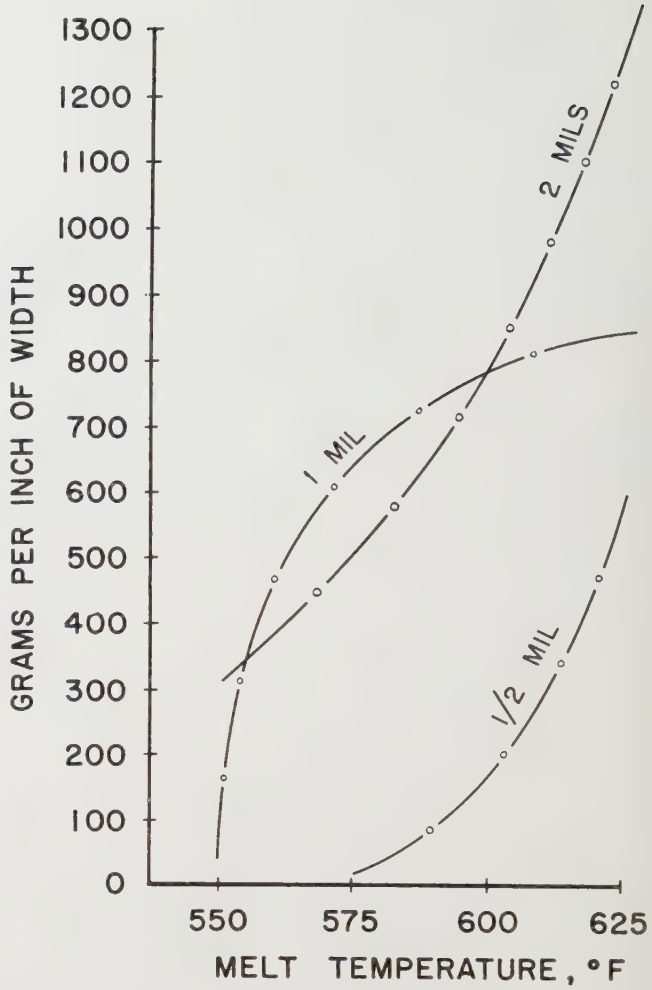

Fig. 10 Adhesion on Mylar®
1/2, 1, and 2 mils—Resin "Y"

levels do not differ greatly, melt properties influence the route taken by each resin toward its peak. Although resins "U" and "V," for example, reach higher points than "W," "X," and "Y," the operating range for achieving good adhesion is more narrow. In practice, while the high melt index resins "W" and "Y" can be extruded from 560 to 600°F. with good adhesion, actual temperatures would be selected at the low part of this range to offset possible neck-in or web handling problems. A further illustration of melt properties is that resins "V" and "X" each have the same curve shape and peak values on Mylar® as they do on foil.

Adhesion of 1-mil coatings on "K" type cellophane as shown in Fig. 8 indicates that this base material has a pronounced influence on adhesion. The curve pattern is similar to that observed for foil and Mylar® but the magnitude of peak values is lower for all resins. At 550 g., resin "W" reaches a higher maximum than the others, consistent with its performance on the other base stocks because of its low viscosity. The average range of 400 to 450 g. for the other polyethylenes, although lower than the levels observed in foil and Mylar®, does indicate adequate adhesion and is typical for "K" type cellophane. The difference in levels is partly caused by the primers. Tyzor AP (TPST) was selected for "K" type cellophane, but both foil and Mylar® were primed with Tyzor AA (titanium acetylacetonate), for reasons previously described. The adhesion similarity of each resin on the two base stocks which had the same primer coating, contrasted with the uniformly lower adhesion of all resins on the differently primed cellophane suggests the effect of the primers.

In addition, the adhesion mechanism is different and more complex on "K" type cellophane than on other smooth substrates. Relative polarity of the component layers in the cellophane coating strongly influences adhesion. Figure 8A is a magnified cross section of polyethylene coated on this substrate, showing the component surfaces. The base cellophane is coated on each side by a polymer layer, indicated by the dark areas, which is physically anchored to the cellophane. The dotted section represents the interfacial primer layer which joins the polyethylene surface to the inside polymer layer. Regardless of the specific primer used, it is a highly polar compound which tends to bond tenaciously to the polyethylene and polymer surfaces. Delamination or adhesion breakdown in this construction can occur in three ways: (1) if the bond between the polyethylene and primer is weak, the polyethylene will strip away from the primer coating; (2) when the polyethylene-primer bond is stronger than the cellophane-polymer bond, delamination will occur between the latter two surfaces, but still appear as weak adhesion in the polyethylene itself; (3) where there is nonuniform adhesion either between the cellophane and polymer layer or between the polyethylene and primer because of caliper variation or other causes, delamination may occur alternately at the two interfacts. Erratic results encountered in adhesion on "K"

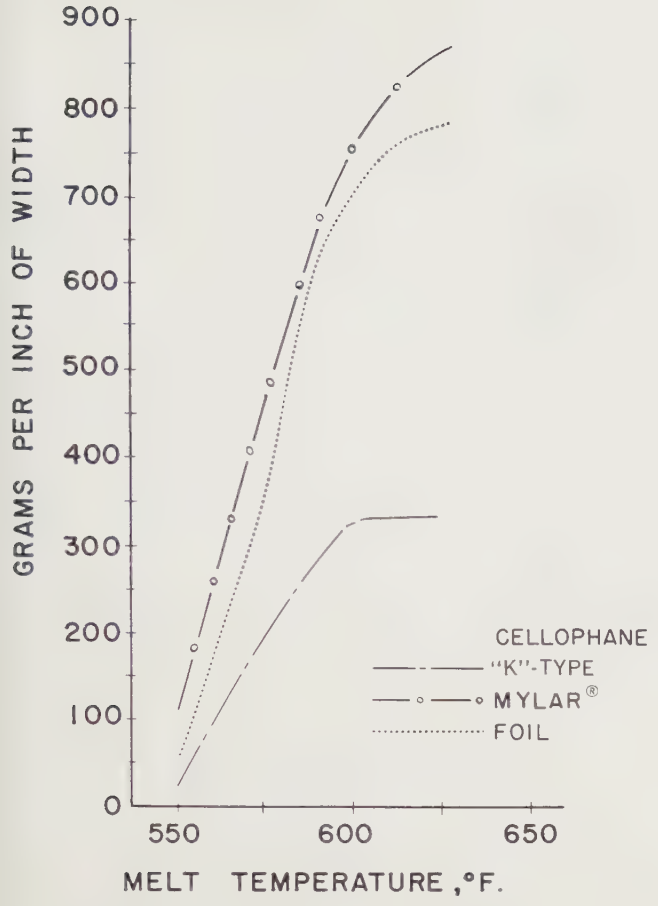

Fig. 11. Adhesion on 1-mil coatings
Composite curves for Cellophane ("K" type), Mylar®, foil

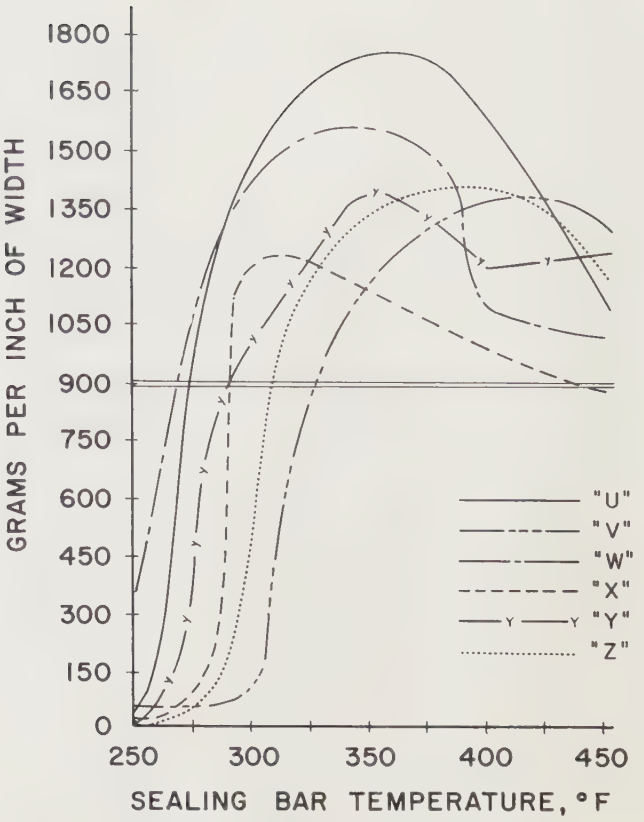

Fig. 12. Heat-seal strength on kraft
Comparison at 600°F., 1 mil—All resins

type cellophane can be caused by this phenomenon. The polyethylene pulls away from the primer in an area of weak adhesion, but breaks through the polymer coating and pulls directly from the cellophane, either because the polyethylene-primer bond increases or the cellophane-polymer bond decreases in strength.

Adhesion on MSAD-type cellophane differs, because of substrate properties, from the type of bonding on other base materials. Polyethylene is applied to the plain or uncoated surfaces, sometimes called the "sweet" side. Molten polymer adheres to the anchored cellophane surface because of intimate contact under pressure. Tack may also develop because of slight softening of the cellophane surface due to heat. The bond formed in this manner is weak, and the polyethylene may be stripped from the cellophane on samples separated shortly after extrusion. Upon aging, however, adhesion increases considerably. This effect is believed to be due primarily to oxidation of the contacting surfaces. Stress relaxation and shrinkage of the polyethylene with time may also aid the adhesion improvement.

Figure 9 compares adhesion on MSAD-type cellophane at three coating weights, using resin "Y" as an example. Peak values are of the same magnitude as in "K" type cellophane, below those of other base materials. The $^1/_2$-mil curve, until the melt temperature reaches 625°F., demonstrates the rapid loss of heat in the air gap from a thin web extruded at high speed. The 1- and 2-mil traces are not significantly different, but show that for coatings of 1 mil or greater there is sufficient heat retention to permit adequate adhesion over a broad operating range. The apex reached at 600°F., followed by a reduction in adhesion at 625°F. is an example of unusual effects sometimes encountered with this substrate. However, there is adequate bond strength throughout the 575 to 625°F. range.

In Fig. 7 adhesion on Mylar® was observed to have similar trends and curve shapes as noted for kraft paper and MSAD-type cellophane, except for the much higher level of bond strength on Mylar®. A vivid illustration is the adhesion of resin "Y" on Mylar® at three coating thicknesses, as shown in Fig. 10. The gain in adhesion due to increased coating weight is the same effect as for other base stocks. The center sections of these curves are more significant than the very high peak values. The latter points correspond roughly to the tensile strength of polyethylene at each thickness. Adhesion is measured during the initial jaw separation on the Instron tester, but some stretching of the polyethylene may occur toward the end of the test, making it difficult to isolate adhesion from tensile strength. In addition, as in MSAD-type cellophane there is probably a slight fusion or blending of heat-softened Mylar® with the polyethylene, since the extrusion temperature is considerably above the melting point of the base sheet.

Figure 11 is a composite picture of adhesion for 1-mil coatings of all resins on Mylar®, foil and "K" type cellophane. These plots were made by averaging the adhesion results of all six resins on these substrates at each increase in melt temperature. The influences of base material properties and primers demonstrate that adhesion on Mylar® and foil for any coating resin will be very similar, both in the rate of adhesion increase and in the final levels attained. Resins coated

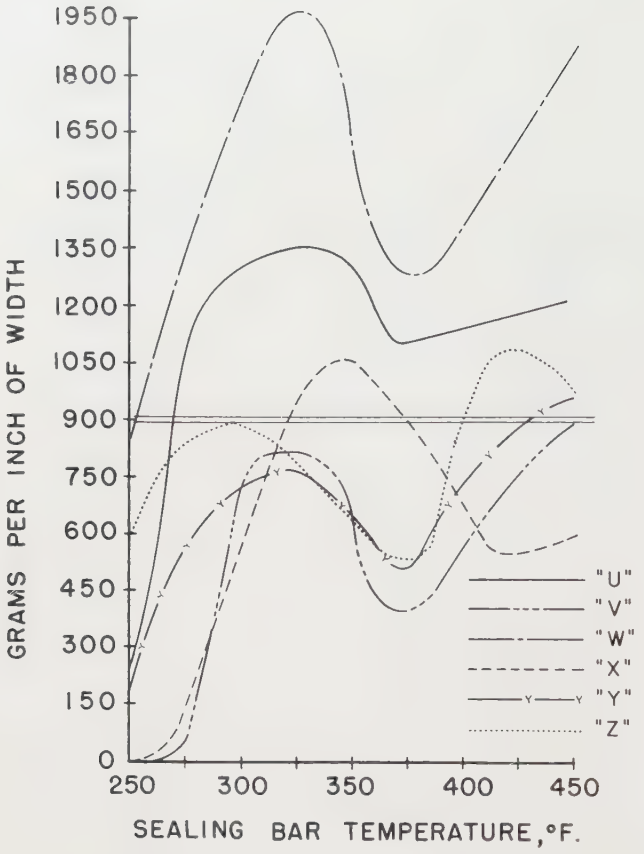

Fig. 13. Heat-seal strength on cellophane ("K" type)
Comparison at 600°F., 1 mil—All resins

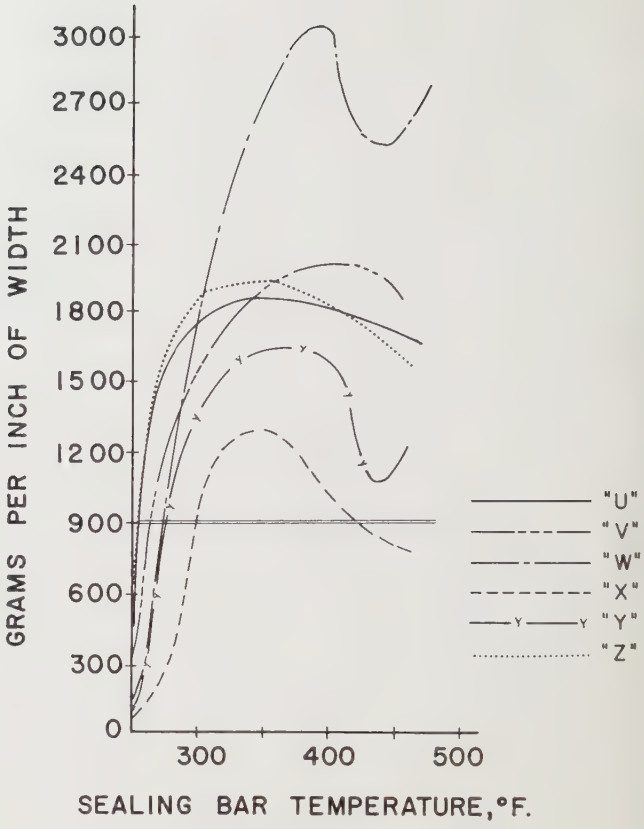

Fig. 14. Heat-seal strength on foil
Comparison at 600°F., 1 mil—All resins

on "K" type cellophane will have a much lower adhesion level, a more gradual improvement in bonding due to melt temperature increase, and a leveling off in the adequate adhesion zone.

HEAT-SEAL STRENGTH

A package is no more effective than the closure or seal. The ability of polyethylene to form a seal under heat and pressure is a primary reason for its use on other materials. It is generally known that resin parameters affect the level of heat-seal strength and the breadth of sealing conditions. However, our study demonstrates that the role of the substrate in modifying the sealing characteristics of a resin is equally important. Both influences must be understood in order to decide on the optimum combination for an effective package.

In the following diagrams on heat-seal strength there is a double horizontal line at 900 g. This represents the "2-lb. pull" level usually considered by the industry as a minimum requirement for heat seal strength. It can serve as a reference line in categorizing coatings as adequate, good, or excellent. Seals were made at a $^1/_2$-sec. dwell time and a bar pressure of 40 p.s.i. These conditions were chosen as representative of settings used on packaging machines for 1-mil coatings. The seal strength results discussed here are relative to the particular conditions, and changes in pressure or dwell time would produce different results. However, the trends to be observed should not differ.

Seal Strength on Kraft Paper

Figure 12 illustrates heat seal strength of 1-mil coatings extruded at a melt temperature of 600°F. for all resins on kraft paper. The dramatic effect of resin density is demonstrated by comparing resins "U" and "X." The very low density of resin "U" results in adequate seal strength at 270°F., a low sealing temperature, and throughout the sealing temperature range to 450°F. high strength values are maintained in resin "U" with a peak at 1790 g. However, resin "X" reaches only 1215 g. and drops off abruptly. The remaining four curves follow the pattern of resin "U," falling between the extremes of "U" and "X." These traces have shapes almost identical to heat seal curves of the same resins for unsupported film. A major difference is that the curves on kraft are displaced toward higher sealing temperatures. In sealing through the kraft at a low temperature, the paper acts like a layer of insulation, preventing the heat from reaching the polyethylene quickly. The heat energy absorbed by the paper does not change when the sealing temperature is increased, because the heat transfer rate is constant; but there is sufficient energy to melt and fuse the plastic.

Seal Strength on "K" Type Cellophane

A comparison of 1-mil coatings at 600°F. on "K" type cellophane is seen in Fig. 13. Heat-seal strength of all six resins differs remarkably from the values on kraft paper. Of greatest significance is that for each resin there is an initial rise to a peak when sealing temperature is raised, and then a characteristic dip at sealing temperatures of 375 to 400°F., followed by a further rise. The consistency of this phenomenon in all resins indicates that it is solely a function of the base material. It is assumed that the dip in heat-seal

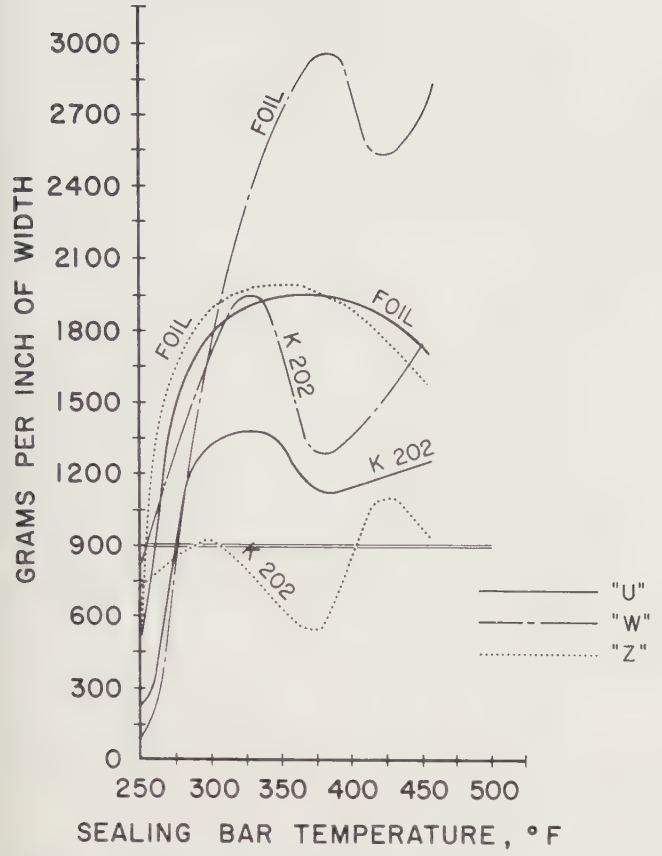

Fig. 15. Heat-seal strength on cellophane ("K"-type) and foil

Comparison at 600°F.—1 mil; resins "U," "W," "Z." Resins in same density class, variable melt index

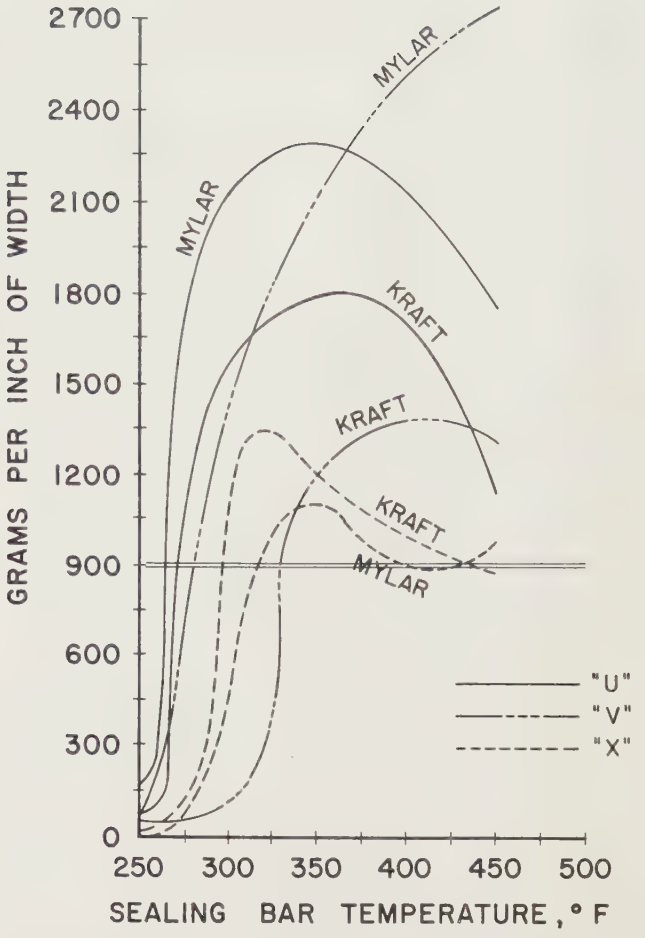

Fig. 16. Heat-seal strength on kraft and Mylar®

Resins "U," "V," "X"—600°F.—1 mil

strength has causes similar to the phenomena observed in adhesion on "K" type cellophane. As sealing temperature is increased past the peak point there is a softening of the polymer coating and then a rupture where the dip occurs. A rise in seal strength past this point indicates possible fusion of the polyethylene and the base cellophane sheet.

Obtaining good strength at a low sealing temperature is desirable for many packaging applications. This can be achieved by raising the melt index or, more important, by lowering the density. In addition, coatings of low density resins usually have the characteristic of being sealable through a broad range of temperatures, as illustrated by resin "U" in Fig. 13. The combined low density and high melt index of resin "W" contribute to its low viscosity at reduced sealing temperatures, so that the coating attains a 2-lb. pull very quickly. Continued increase in melt flow with temperature rise permits very close contact with the base sheet, which increases seal strength to a very high level.

As observed throughout this discussion, melt index and density significantly influence the temperature-viscosity relationships of resins and their consequent effects on coating properties. While useful for predicting expected trends, these parameters alone do not completely determine results, as evidenced by the anomalies which occur in comparing resins. A case in point is resin "Z" in Fig. 13. Its low density and moderately high melt index should result in good low-temperature heat seals, a fairly high level of seal strength, and a broad sealing range. The coating does have good strength at 250°F. but barely reaches the 900-g. mark, until 400°F. is attained. The base material, of course, is another influence in this case. The important point is that density and melt index are good measurements of melt flow properties, but neglect of their interaction with other factors such as molecular weight distribution can lead to oversimplification.

Seal Strength on Aluminum Foil

Figure 14 compares seal strength on foil for 1-mil coatings of all resins at 600°F. The heat-seal characteristics of foil coatings closely parallel kraft paper. Values are well above the 900-g. level for all resins. In addition, seal strength consistently is higher than for kraft, which is an excellent illustration of heat being transferred very rapidly through the foil to the polyethylene during sealing. In discussing adhesion it was noted that good bonding was possible at low melt temperatures. Low sealing temperatures also would be desirable, and this is possible because of good seal strength below 300°F. due to the small loss of sealing-bar heat through the foil.

As in the seal strength comparisons on other substrates, resin "W" demonstrates considerably greater values than the other polymers. The narrow sealing range and relatively lower strength level for the 0.930-density resin "X," and the grouping of the other four resins between the extremes illustrate an important distinction. Comparing coatings of a single resin on several substrates demonstrates that seal strength varies on each base material. When the same com-

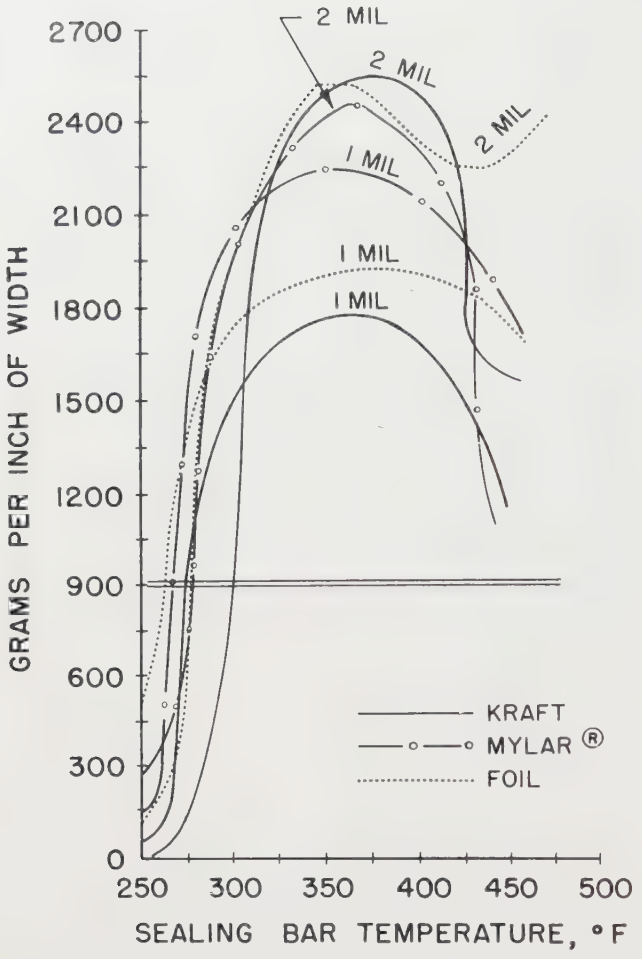

Fig. 17. Heat-seal strength on kraft, Mylar® and foil
Resin "U"—600°F.—1 and 2 mils

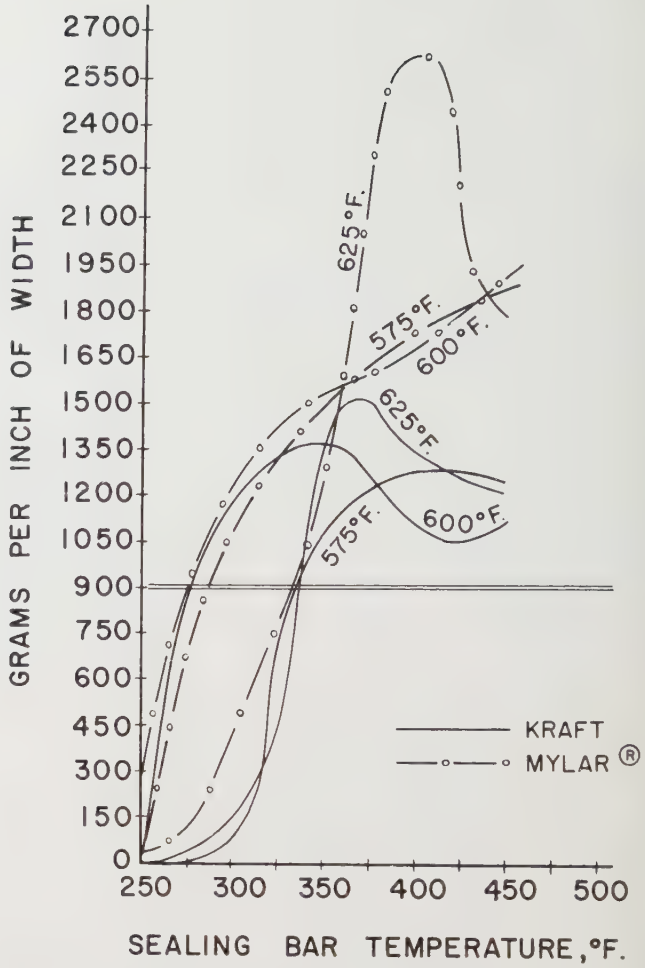

Fig. 18. Heat-seal strength on kraft and Mylar®
Comparison at 575-600-625°F.; 1 mil—Resin "Y"

parison is made using six resins instead of one, as in the last three diagrams, it is noted that although overall strength levels differ on each base sheet, the ranking or relative strengths of the resins among themselves do not fluctuate greatly. Comparative differences in seal strength level for the various base sheets are about the same, regardless of which resin is used as an example. This suggests the predominant influence of the base material in determining heat-seal strength, and indicates that the sealing performance of a resin must be judged in terms of a particular substrate.

Resin Influences on Sealing

Figure 15 depicts the effect of melt index on heat-seal strength for three resins on "K" type cellophane and foil. The substrate influence just discussed again is shown here; for every resin the foil traces have a sharper rise and a higher peak than the respective cellophane curves. For example, resin "W" has a seal strength close to 3000 g. on foil, compared to a maximum of 1900 g. on "K" type cellophane. It is also notable that the very high melt index accentuates the differences in base materials, since the spread among substrates is greater for resin "W" than for "U" or "Z."

A companion graph to the diagram on melt index variation is shown in Fig. 16, where there is a comparison of resins "U," "V," and "X," having the same melt index but different densities. Coatings on Mylar® and kraft illustrate the comparison. The expected effect is that a low density should result in high-strength seals through a wide temperature range, with opposite results for a high-density resin. This is shown particularly by the Mylar® coatings for resins "U" and "X" at the lower and upper ends of the density range, 0.915 to 0.930. Resin "V" has a greater strength at a 450°F. sealing temperature than resin "U," although "U" has the lower density and should be above "V." Rather than a reversal of the density trend, this is probably the same effect as in adhesion: a possible softening of the surface of the Mylar® and partial fusion of the Mylar® and polyethylene.

The curves for kraft demonstrate the same pattern as in Mylar®, with the lower density resin "U" having higher seal strength through a broader range than "V" or "X." As noted in Fig. 15, where high melt index tended to emphasize substrate effects on sealing, there is a similar influence here from density. At the 0.930-density strength values are considerably less than for the lower density resin. Seals for kraft and Mylar® are not significantly different, and the influence of substrate on seal strength becomes dampened to the point of reversal, since for the other resins seal strength was much higher on Mylar® than on kraft.

Effect of Extrusion Variables on Sealing

The influence of coating thickness on seal strength for a particular resin is demonstrated in Fig. 17. Coatings on each of three base sheets at 1 and 2 mils clearly show a corresponding increase in seal strength when

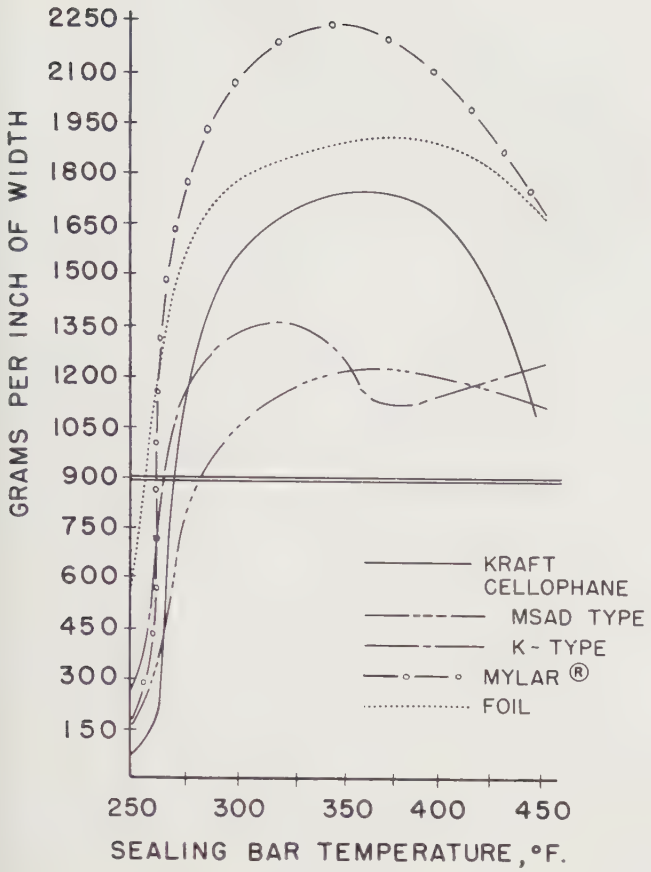

Fig. 19. Heat-seal strength resin "U"
Comparison at 600°F.; 1 mil—all substrates

gage is increased. There is a definite separation in the family of 1-mil curves, illustrating the interplay of subtle differences in base material surfaces, primers, and heat transfer rates of the substrates. The effect of these variables is overshadowed in the 2-mil coatings by the increase in gage, and the curves nest closer together. All of the traces for Mylar® and foil follow a typical sealing pattern, with high initial and final strength levels in a broad temperature range.

In discussing adhesion it was seen that a rise in either coating weight or melt temperature tends to improve the bond. There is a similar effect in heat-seal strength from gage, but at a particular thickness, do coatings extruded at higher melt temperatures exhibit greater seal strength? Further, if there is such an effect, of what magnitude is it? Figure 18 illustrates seal strengths on 1-mil kraft and Mylar® coatings at melt temperatures of 575, 600, and 625°F., using resin "Y" as an example. Looking first at kraft, the high points of each curve occur at different sealing temperatures, but if ranked according to average strength levels, a higher melt temperature seems to cause a slight rise in sealing strength. Ordinarily, increased temperatures reduce heat-seal strength because of oxidation, particularly in an extended air gap. In this case the very short air gap resulted in no pronounced effect on seal strength because of melt temperature.

Analysis of the adhesion and sealing peel tests also indicates that increased melt temperature does not necessarily cause better seal strength. Both sealing and adhesion involve melting of the polyethylene. But in testing adhesion, polyethylene is peeled from the substrate surface; while in testing seal strength, layers of polyethylene are separated from each other. If three coatings made at different melt temperatures are sealed at the same bar temperature, the amount of remelting should be about equal, and the polyethylene-to-polyethylene bonds should be of about equal strength. Where a higher melt temperature samples seems to have greater seal strength, the peeling probably is occurring both as a separation of the two polyethylene surfaces and a separation of the polyethylene from the substrate; in this case the seal-strength value becomes partially colored by adhesion. The curves for Mylar® at 575 and 600°F. show very little difference in seal strength, but the 625°F. trace indicates a much higher value. This curve is an example of a false reading. If adhesion correlates closely with heat-seal strength, then there should be some proportionality in the improvement of each as melt temperature rises. Actual adhesion values increased 12% from 575 to 600°F., and 13% from 600 to 625°F. Respective changes in seal strength at a bar temperature of 400°F., where the high peak occurs, were −6% and +38%.

A phenomenon frequently encountered in sealing is shown in Fig. 16 by the meeting of the three Mylar® curves at a sealing temperature of 445°F. The very high peak and sudden drop of the 625°F. curve has been noted for other sealing traces, and probably results from a "bead" effect. On some seals, instead of a polyethylene layer of uniform thickness, molten plastic is squeezed by pressure and high flow rate to the edge of the seal, forming a bead. In attempting to pull the seal apart, the bead is thick enough to resist a very strong peeling force; but after the bead is broken through, the plastic layer becomes relatively thin, offers less resistance to peel, and shows an abrupt reduction in strength.

Base Material Effects on Sealing

The previous discussion has emphasized the influence of substrates on heat-seal strength. A vivid example is the family of curves in Fig. 19, comparing 1-mil coatings of resin "U" on all five base sheets. Causes of the individual substrate influences have been analyzed, and the collective pattern of the results can be seen here. The Mylar® coating has the greastest value; foil ranks slightly above kraft with their curves almost parallel, and the cellophanes fall in the lower part of the seal strength scale. Resin effects which accompany a low density polymer are also apparent. Each base material has seal strengths well above the 2-lb. pull mark, and except for "K" type cellophane with its characteristic dip, the traces have a broad sweep covering the full heat sealing range.

It was also observed that the substrate influence on heat-seal strength is most pronounced in a low-density resin, and that the opposite density extreme dampens the base sheet effects. In changing from resin "U" at a 0.915 density to resin "X" at 0.930, as shown in Fig. 20, the substrate curves follow one another very closely. Contrasted to a spread of peak values from 1250 to 2250 g. for resin "U," the range for resin "X" is drastically reduced, falling between 950 and 1350 g. This diminishes the relative differences among base materials, which together with the narrow sealing range resulting from the high resin density, gives an

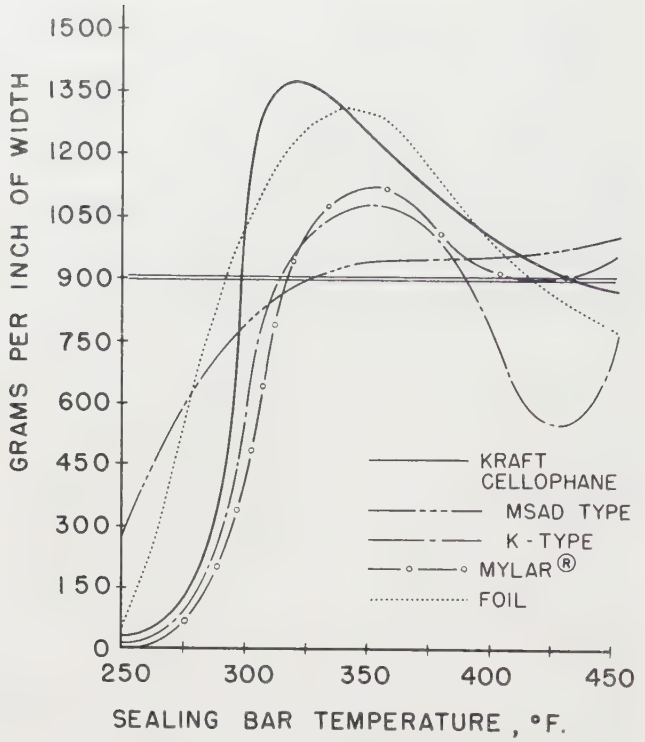

Fig. 20. Heat-seal strength, resin "X"
Comparison at 600°F., 1 mil—all substrates

appearance of rather uniform sealing characteristics for all substrates.

From averaging the data for each resin on the various base sheets, it is possible to depict typical curves which most resins should follow. The composite curves in Fig. 21 shows plots for three of the substrates—kraft paper, "K" type cellophane and foil—which result from averaging the heat seal strength of the six resins at each sealing bar temperature. The curves from kraft and cellophane are most strongly influenced by the 0.923- and 0.930-density resins, and would be displaced left toward lower sealing temperatures for a low density resin. The rapid rise and wide sweep for sealing strength on foil, the peak and dip on "K" type cellophane, and the relative strength levels of the base materials are typical of the performance of coating resins.

DRAW RATE AND NECK-IN

In addition to heat seal and adhesion properties of a coating resin on a specific base material, two factors which help to characterize resin performance more completely are neck-in and draw rate. As an example, if the production objective was to coat 0.2 mil at 1000 f.p.m., a resin with limited draw rate would be unsuitable, despite good heat seal properties. A draw rate comparison of the six resins used in this study is shown in Table II. Draw rate limit is the feet-per-minute rate above which there is weaving of the web,

Table II. Draw Rate, F.P.M.

Resin	*Density, g./cc.*	*Melt index*	*2¾ in. air gap* 575°F.	625 °F.	*5-in. air gap* 575°F.	625°F.
"U"	0.917	3.4	357	615	415	650
"V"	0.923	3.1	450	900	520	951
"W"	0.915	23.0	>1025 (Equipment limit)			
"X"	0.930	3.0	440	900	500	930
"Y"	0.923	8.0	>1025 (Equipment limit)			
"Z"	0.918	10.0	495	990	525	>1025

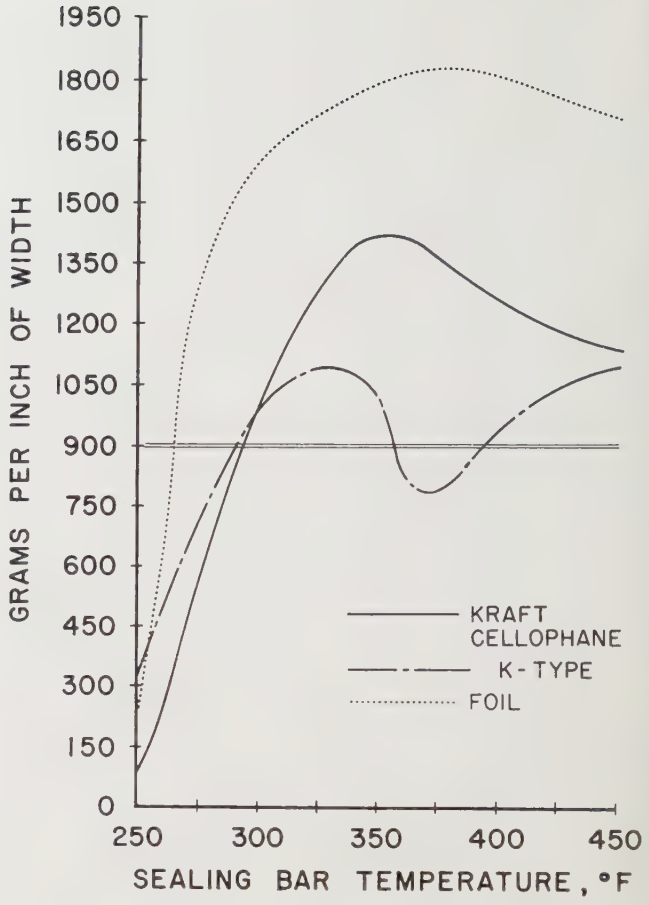

Fig. 21. Heat-seal strength at 600°F.—1 mil
Composite curves for kraft—cellophane ("K" type) foil

tearing, or both. Numbers in this table are speeds at which the web extruded steadily for a minimum of 10 min. Die opening and output were held constant at 20 mils and 150 lb. per hr., respectively. In analyzing these data it sould be noted that higher or lower outputs would change the speeds attained; however, relative comparison of the resins would be unaffected.

Immediately noticeable is the fact that two resins, "W" and "Y," had drawability to the maximum machine speed of 1025 f.p.m. throughout the air gap and temperature changes. Primarily, this is a melt index effect. Resin "V," which has the same density as "Y" but a lower melt index, does not approach the draw rate of "Y" except at the long air gap and high melt temperature. Resins "V," "X," and "Z" have similar draw characteristics, demonstrating that the variations among them in melt index and density are offset by these parameters and other melt properties. It will be observed that resin"U" has less drawability

Table III. Neck-in

Resin	*Inches of neck-in*
"U"	0.7
"V"	1.4
"W"	2.5
"X"	1.6
"Y"	1.7
"Z"	1.5

Die slit width, in.	24
Die opening, mils	20
Melt temperature, °F.	600
Air gap, in.	2¾
Film thickness, mil	1
Takeoff rate, f.p.m.	220

than any of the other resins, and contrasts sharply with "Z," again showing the effect of melt index. Table II also demonstrates that the rate can be increased either by extruding at a higher melt temperature, or by increasing the air-gap length at the same temperature.

In addition to the influence of draw rate on production speeds and costs, neck-in also affects the coating output. Table III is a tabulation of total inches of neck-in at a given set of extrusion conditions. Significant points are that one resin,"U," has almost no neck-in, resin "W" shows severe neck-in, and the other resins are grouped closely between them. Extremes in resin parameters account for the gross differences, "W" being influenced by its extremely high melt index and "U" by its combined low density and low melt index. These results show that both draw rate and neck-in must be used to modify the adhesion and heat seal properties of a resin, to fairly appraise performance.

SUMMARY

1. Coatings of low density resins result in a broad heat seal temperature range and relatively high levels of seal strength. The converse is true for higher density resins of the same melt index and, in addition, seal strength differences among substrates are minimized by higher density in combination with a narrow molecular weight distribution.

2. The desirable effect of reduced sealing temperatures in low density resins is accentuated by raising the melt index. Increased seal strength can be expected in coatings of higher melt index resins because of decreased viscosity during sealing, throughout the sealing temperature range.

3. It was found that regardless of resin parameters, particular substrates used have a strong influence on seal strength level. For the six resins studied there was higher seal strength in coatings on Mylar®, aluminum foil and kraft paper than on the cellophanes.

4. Melt index is the resin parameter having the greatest effect on adhesion. Coatings of higher melt index resins attain adhesion at low extrusion temperatures because of reduced viscosity, compared to coatings of low melt index resins at equivalent temperatures.

5 Differences in surface properties and primers on smooth base materials result in variations in the adhesion levels attained.

6. Temperature of the polyethylene at the instant it contacts the web affects adhesion critically. This unknown temperature can be controlled only through the melt temperature, which demands balancing of resin and substrate influences with thickness, air-gap length, and linear rate.

7. Density, melt index, molecular weight distribution, and other melt parameters combine to influence resin behavior, although a single characteristic may have a primary influence on a certain coating property.

8. Since variations in base material properties affect adhesion and heat-seal strength levels, resin performance should be measured in terms of particular substrates.

Received Dec. 2, 1959. Presented at the 14th Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, held in Chicago, Ill., Sept. 21–23, 1959.

Effects of Electrolytes in the Valley Beater Test

BERWYN B. THOMAS

A bleached, pine kraft pulp was beaten in the presence of a number of ionic salts, freeness and sheet properties being measured. On a constant freeness comparison basis (400 C.S.), polyvalent cations increased beating time and air resistance most notably, and strength tests less. On constant time basis, however, changes were much less marked. Specific surface of fiber slurries in various waters was determined by the permeability method of Robertson and Mason. Surface correlated well with freeness, but not with burst strength when samples had all been beaten an equal time in various waters. The data support Yorston's mechanism of electrostatic effects of ions on fibers. The effects on freeness are due to contraction of the fibrils, with resultant opening of flow channels, and bonding power is affected little. Pulps of various types were beaten comparably in tap water and deionized water. Kraft pulps all showed much faster freeness reduction in deionized water. Sulfite pulps were affected less or not at all. No correlation of this result with any analytical quality has been found. Specification of deionized water as testing medium in calibration of beaters and freeness testers is recommended.

That electrolytes present in the water can affect the course of the beating process and the dispersion of fibers has been known for many years. The first comprehensive study related to this subject was apparently reported by Bell (*1*) in 1933. This and other early work by Yorston (*2*) and Specht and Connor (*3, 4*) showed that polyvalent metal ions had significant effects of increasing the apparent freeness of a pulp slurry. Yorston proposed, as a mechanism, that the ions caused the fine cellulose fibrils to become less mutually repellent and to draw together. This would result in closing the finest passages between fibrils but opening wider the larger passages between separate fibers, and allowing greater flow through a slurry. Lottermoser (*5*) reported data on coagulation of cellulose sols by ions, which supported this mechanism.

Adams, Simmonds, and Baird (*6*) studied the effect of acids and electrolytes on freeness in 1938. They agreed with the previous work, finding that apparent freeness was increased more by polyvalent ions than by monovalent ones, and that pH had little effect by itself. They also found that the effects increased with beating but that some pulps were more sensitive than others. Other experimenters of this period, who generally supported the mechanism of colloidal effects described above, were Reed (*7*), Cottrall and Gartshore (*8*), and Edge (*9*). More recent work has been done in Australia, as described below, and in Italy by Centola and Borruso (*27,28*).

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The practical importance of electrolyte effects was first well realized in Australia. Great difficulty was met in obtaining corresponding tests on pulp samples at different mills, and the cause was found in the water composition (*10*). Intensive studies were reported by Cohen, Farrant, and Watson (*11*, *12*) in which spruce, pine, hemlock, and eucalyptus pulps were beaten in the Lampen mill in various ionic solutions. The effect on freeness was found to be proportionately greater than that on strength. All cations increased freeness, with the effect increasing with ion valence. Burst strength was increased by alkali ions, decreased by multivalent cations. Little or no effect could be attributed to anions except hexametaphosphate, which produced notable effects on sheet properties at very low concentration.

As a result of this work, distilled water is now specified for Lampen mill beating and for dilution of beaten samples up to the actual sheetmold in Australian Standard methods (*13*). With the exception of one Melbourne mill which has excellent natural water, distilled water is also generally used for sheetmaking in Australia (*14*).

The Pulp and Paper Research Institute of Canada has recently adopted distilled water for standard use in beating and dilution up to the sheetmold, and the possible need for a specification on this factor was a subject of discussion at a recent Canadian convention (*15*).

The Finnish Technical Association has recently adopted distilled water as a standard for certain steps in the beating test (*16*).

About 1955, TAPPI obtained a sample of western hemlock sulfite pulp which was set aside as a reference beater standard. Samples have been tested in many laboratories and efforts have been made to condense the data to "normal" values of freeness and strength tests (*17*). However, there are no TAPPI specifications for water composition in the beater test. This uncontrolled factor can be expected to have some effect on results obtained at different mills, and thus on the degree of precision which can be attained on the reference pulp. The same limitations must apply to any other comparison involving more than one location. They may also be concerned in comparison of tests made at different seasons, if water composition varies.

Since the proposed mechanism of electrolyte effects involves changes in fibril arrangements, a fundamental approach to its study was sought, and measurement of specific surface was selected. Estimates of this quality can be obtained by several methods, including silvering, optical examination, and gas and liquid permeability. Relative merits of these methods have been discussed by Mason (*18*) and Emerton (*19*), permeability being preferred. Furthermore, liquid permeability offered the advantage of testing under conditions closely similar to those of the freeness test and sheet formation. An apparatus for this measurement and its operation have been described by Robertson and Mason (*20*). These authors, as well as Corte (*21*), Thode and Ingmanson (*22*), and Borruso (*28*), have discussed the relation between specific surface and strength properties.

The present experiments were made to test the effects of water composition on various aspects of the beating process. Much of the aforecited work was done by dilution of prebeaten stock with electrolyte solutions or was carried out by methods not commonly used in this country. There was little direct evidence, therefore, based on the Valley beater and showing effects of the electrolytes on the beating itself.

In the experimental work, three approaches were used: (1) beatings were made on a control pulp in solutions of a large number of different ionic salts, freeness and sheet properties being determined, (2) specific surfaces of some samples from these beater tests were determined by the permeability method; (3) a number of different pulps were beaten comparatively in deionized and "tap" water.

EXPERIMENTAL

Methods and Materials

Beater tests were run in a new, standard Valley beater. The beater was ground in with 80-grit carborundum and maintained by Dinger's touchup method (*23*). The beating procedure followed TAPPI T 200 m-45 with modifications which have been found necessary to give samples large enough for the desired tests. Thus the charge in the beater was 445 g. ovendry pulp in 25 l. of water, sampled by withdrawal of 1400 ml. at 15–min. intervals. Beater-arm weight was 4500 g. for the first part of the work, 4700 for later experiments after a restandardization. Each beater interval sample was diluted to 0.45% and divided for making freeness

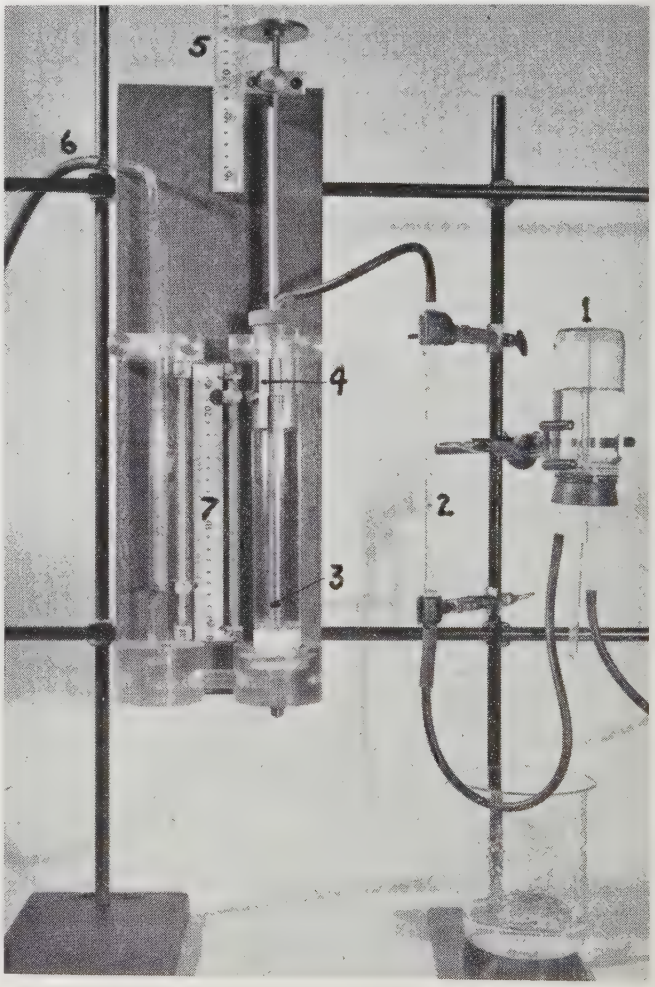

Fig. 1. Water permeability apparatus components

1—constant head bottle; 2—flow meter; 3—sample tube with compressing piston; 4—cap with 270° sector plug; 5—piston height scale; 6—vacuum draw-off; 7—head-height scales

tests and nine handsheets. Test sheets were made, dried and tested in accordance with the appropriate TAPPI Standards.

Water permeability measurements were made with an apparatus designed and operated after that of Robertson and Mason (*20*) and shown in Fig. 1. The principal changes were (1) addition of reference scales and markers for measurement of head and piston height, (2) partial filling of the top of the sample tube with a 270° sector plug to reduce the volume change associated with head changes, and (3) replacement of the flow volume measurement by a falling-ball flowmeter. The meter used was a Fischer-Porter Flowrator No. 02F-1/8-12-5 with sapphire ball, calibrated by the manufacturer's specifications (*24*). With these additions, readings could be made very rapidly with minimum error from compaction of the fibers. The total liquid passed through each pad during a series of tests at increasing consistency was 50 to 100 ml. Flow rates were 0.03 to 0.3 ml. per sec.

The mathematical basis of the water permeability test was also discussed by Robertson and Mason (*20*). Factors recorded for each measurement included:

W = dry weight of fiber sample
H = head difference across fiber pad
L = height of piston (or of the fiber pad)
Q = flow rate through meter

Constant factors were the tube cross section A, gravity constant g, and the viscosity η and density ρ of the water. (It was assumed that variations in the last two factors due to electrolytes were negligible in the dilute solutions used.)

Calculation required determination of a flow constant K and the consistency C.

$$K = Q\eta L/g\rho AH = 1.326 \times 10^{-6}\, QL/H$$
$$C = W/AL = W/7.36\, L$$

If the quantity $(KC^2)^{1/3}$ is plotted against C, a straight line should result. The specific surface (σ) was calculated from the intercept (I) obtained for $(KC^2)^{1/3}$ at $C \rightarrow 0$ by extrapolation.

$$I = \underset{C \rightarrow 0}{(KC^2)^{1/3}} = (5.55\ \sigma^2)^{1/3}$$
$$\sigma = 0.424\, I^{-3/2}$$

The deionized water used was prepared from well water or from power steam condensate with mixed bed resin units in regular laboratory service. The "tap" water was a well water, filtered but not treated chemically. Its ionic content included 17 p.p.m. of silica, 18 of calcium, and 20 of sodium. These and other very minor metal ions were equal to about 2.8 milliequivalents per liter. All the chemicals used were reagent grades, and electrolyte solutions were made up using the deionized water.

The pulp used for the first two sections of the work was Georgianier, a bleached southern pine conventional kraft made by Rayonier for papermaking use. Several other pulp grades, from various sources, were included in the final part of the work.

Comparison of Electrolytes

Each electrolyte was tested in duplicate beater runs at two or more concentrations between 0.00025 and 0.004 molar. The individual tests were arranged in a random order and interspersed with control tests using alternately deionized or tap water without added electrolytes.

Table I. Kraft Pulp Beaten in 0.002 *N* Electrolyte Solutions
Beating Summary at 400 C. S. Freeness

Electrolyte or water used	*Beating time, min.*	*Burst, %*	*Air resistance, sec.*
Deion. water[a]	47	134	14
Deion. water[b]	47	131	12
Tap water[c]	63	146	46
Zeolite water[d]	51	140	26
NH_4Cl	56	139	30
Na_2SO_4	55	143	30
$LiCl$	55	142	26
$NaNO_3$	55	137	30
KCl	54	143	27
$NaAc$	54	137	25
$NaAlO_2$	52	142	25
Na_2SiO_3	51	142	18
Na_3PO_4	51	139	20
$Na_2B_4O_7$	50	143	22
Na_4EDTA	50	140	22
$(NaPO_3)_6$	49	139	21
$MgCl_2$	63	143	34
$CaCl_2$	65	146	55
$CaAc_2$	66	145	67
$MnSO_4$	67	145	59
$ZnCl_2$	67	145	71
$FeCl_2$	67	146	45
$CuCl_2$	67	150	63
$FeCl_3$	67	147	33
$AlAc_3$	70	141	45
$AlCl_3$	70	145	66
$CeSO_4$[e]	70+	~145	60+
$ZrSO_4$[e]	70+	~145	60+
Significant diff. (95%)	4	8	15

[a] For beating and sheetmaking.
[b] For beating; tap water for sheetmaking.
[c] About 0.0028 *N* equivalent.
[d] Assumed same normality as tap water.
[e] Tested only at 0.001 *N*.

For each test, the pertinent solution was used for filling the beater, diluting the interval samples to 0.45%,

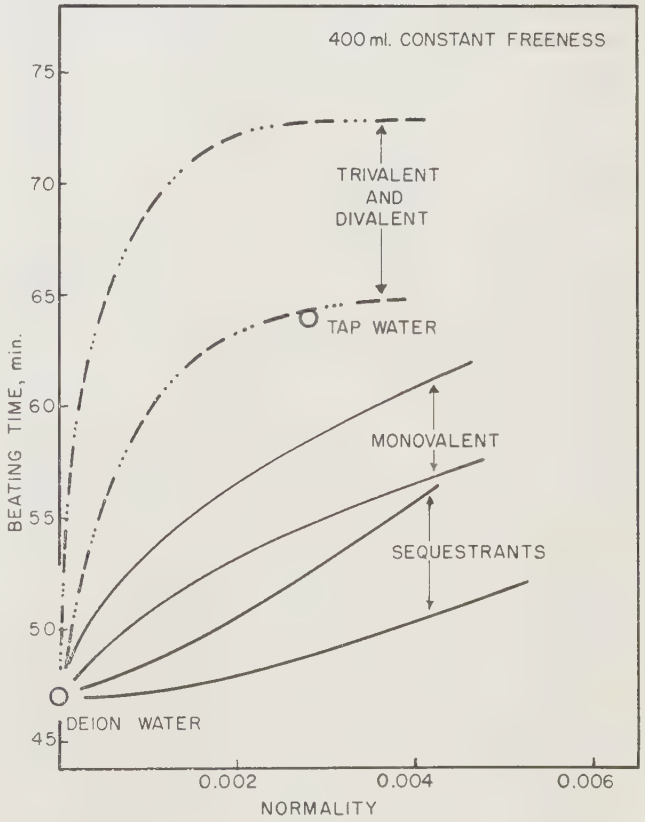

Fig. 2. Effect of electrolyte on beating time to 400 ml. freeness

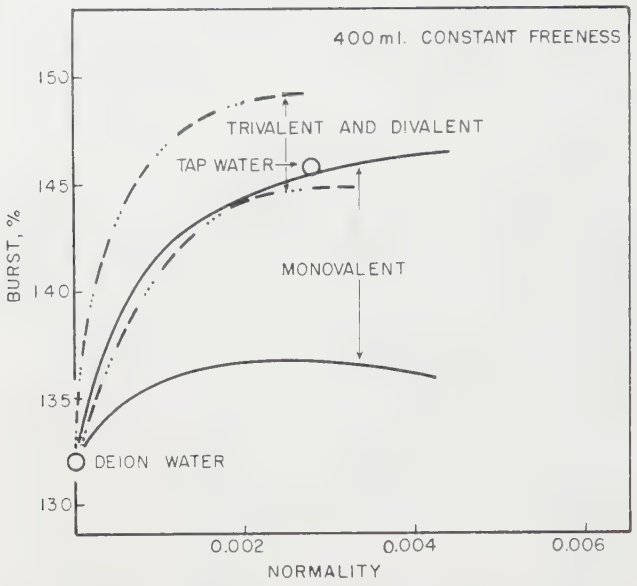

Fig. 3. Effect of electrolyte on burst strength at 400 ml. freeness

and completing dilution of the freeness samples. As has been found practical in various other locations, tap water was used to fill the sheetmold. A careful check was made which showed that little if any effect on sheet strength and structure could be traced to this exposure of the fibers to tap water.

The electrolytes tested are listed in Table I. They included both cations and anions with valences from 1 to 4. Some of the anions were sequestering agents, including sodium hexametaphosphate and ethylene-

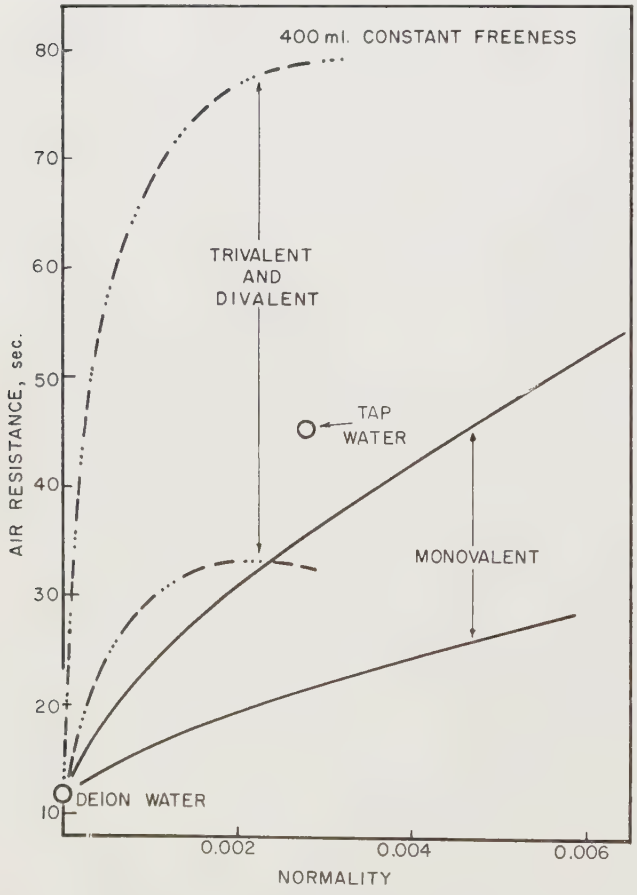

Fig. 4. Effect of electrolyte on air resistance at 400 ml. freeness

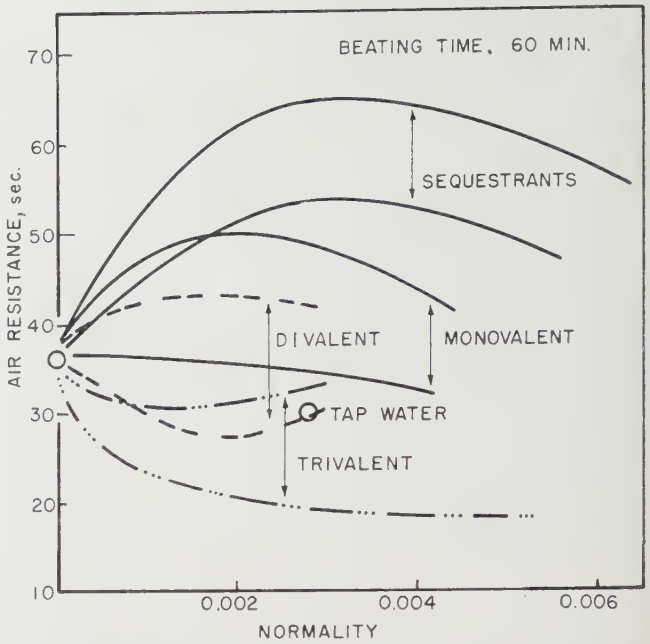

Fig. 5. Effect of electrolyte on air resistance at constant beating time

diamine tetraacetate ("Versene"). To condense the mass of experimental data to comparable figures, individual beating curves were first interpolated at 400 ml. C.S. freeness. These data were plotted against concentration of the respective electrolytes, as in the following figures, and another interpolation made at 0.002 *N* for the data of Table I.

A statistical analysis was made of the variability of the individual test results. From this were obtained estimates of the significant difference limits (95% confidence level) as shown in Table I.

An alternative method of condensation of the data is used in the accompanying figures. Figure 2 shows beating time changes, with increasing electrolyte normality, at 400 C.S. freeness. The individual curves are not shown; they fall within the general areas marked in the figure. Similarly, Figs., 3 and 4 show the ranges of variation of burst strength and air resistance of the corresponding hand sheets.

Tensile test data showed a dispersion similar to that of the burst tests. Values of breaking length ranged from 7300 m. for deionized water upward to 8600 m., the significant difference being 500 m. Other tests showed smaller or little variation; these included tear, fold, shrinkage, density, and stretch.

Since Fig. 2 represents time to a constant freeness, it is also generally similar to a plot of freeness at constant time. Freeness at 60 min. varied from about 300 ml. for deionized water to 500 ml. for the highest part of the range.

For sheet test data, plots at constant time showed little dispersion. As an example, that for air resistance tests after 60 min. beating is given in Fig. 5, while others showed even less distinction between the effects of monovalent and polyvalent ions.

If sequestering agents are added to solutions containing polyvalent metal ions, much of the apparent change in freeness can be overcome. Table II contains test data obtained on several samples beaten with calcium, iron, or aluminum ions in comparison with samples beaten with the same ions plus added hexametaphos-

Table II. Suppression of Electrolyte Effects by Sequestrants or Softening

With metal ion only				With sequestrant added,[a] or softened			
Added ion and normality	*Time, min.*	*Burst, %*	*Air resist., sec.*	*Added agent and normality*	*Time, min.*	*Burst, %*	*Air resist., sec.*
0.0005 Ca^{+2}	62	150	44	0.0006 $(NaPO_3)_6$	57	143	30
				0.001 Na_4EDTA	53	140	30
0.00075 Fe^{+3}	65	153	32	0.001 Na_4EDTA[b]	56	144	35
0.00075 Al^{+3}	67	141	53	0.0006 $(NaPO_3)_6$	52	141	25
(Tap water)	62	147	47	0.0006 $(NaPO_3)_6$	60	148	41
				(Zeolite softened)	51	140	26

[a] In presence of metal ion as given at left.
[b] Ion—specific type.

phate or Versene. Hexametaphosphate was also added to tap water, while another sample was beaten in Zeolite-softened tap water.

Specific Surface Measurements

Using the apparatus described above, two series of specific surface experiments were made. For the first, portions of the pine kraft pulp were beaten for 5, 30, and 60 min. in deionized water. The stocks were centrifuged. Samples were then made up by dilution to 15 g.p.l. in various waters and tested for freeness and permeability rate. Waters tested included deionized water, $AlCl_3$ solution, water at pH 4 and 10, and tap waters from three Rayonier mills in the Olympic Peninsula. These last gave equivalent results. Specific surface and freeness for all the samples are shown as Series 1 in Fig. 6.

The second series of samples tested for specific surface was taken from the electrolyte tests of the previous section of this work. This group included most of the samples specifically shown in Table II containing polyvalent ions with and without sequestering agents. The beater runs were sampled at 45 min. and the sample diluted with the corresponding solution for test. These data are shown as Series 2 in Fig. 6, in comparison with their freeness, and in Fig. 7 in comparison with the burst strengths of handsheets made from the same beater intervals.

Comparison of Various Pulps

When the test program was extended to pulps other than the pine kraft previously mentioned, it was found that not all pulps were equally responsive to the electrolyte content of the local tap water. Comparative beatings were then made in tap and deionized water on a number of pulps of various types and sources. These are listed in Table III, with data on beating time, burst, and air resistance of the handsheets at 400 C.S. freeness. Besides Georgianier, the southern prehydrolyzed and hardwood kraft pulps and the pine, hemlock, and acetate grade sulfites were made by Rayonier, while others came from various other manufacturers. The cotton linters were a commercial grade modified by partial substitution with ethylene oxide.

To eliminate the possibility of error in test method or uniqueness of the available tap water, two of the tests were repeated in a distant laboratory, as shown. The results agreed with those previously found.

DISCUSSION

A basis of equal freeness was selected for comparison of the test data because this basis is often used in mill operations. As Fig. 2 shows, addition of any ionic material caused the beating time to this constant freeness level to increase, as much as 70%. The increase was gradual with monovalent cations and lowest with

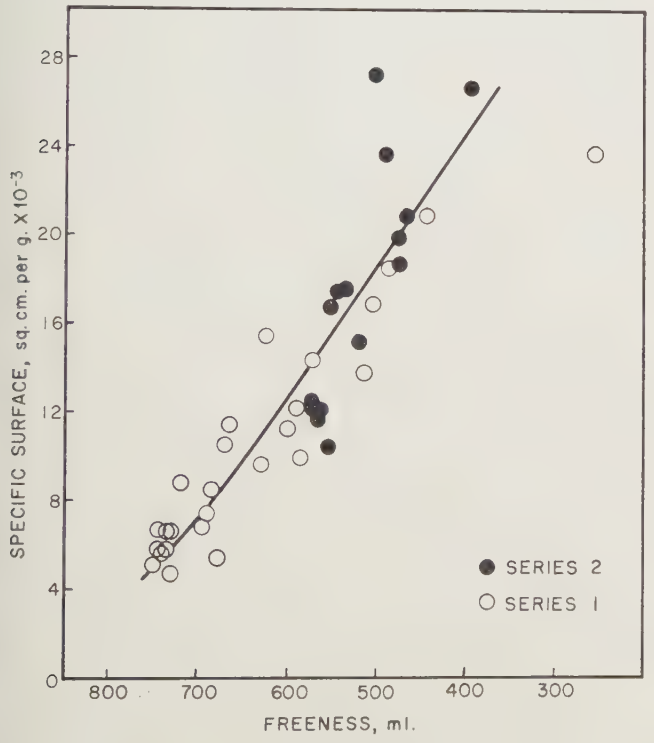

Fig. 6. Freeness versus specific surface of beaten pulps

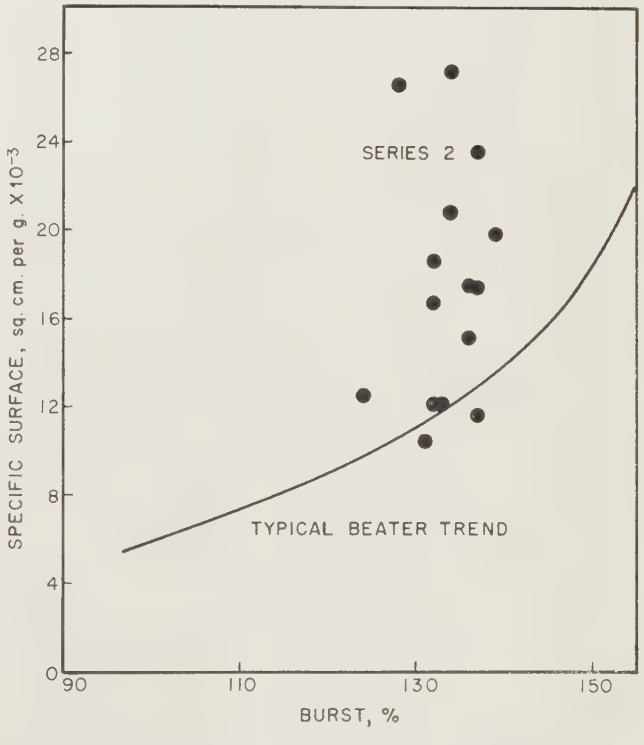

Fig. 7. Burst versus specific surface of beaten pulps

Table III. Comparison of Beatings in Deionized and Tap Waters

Beating Summary at 400 C. S. Freeness

Water →	Time, min. Deion.	Time, min. Tap	Burst, % Deion.	Burst, % Tap	Air resistance, sec. Deion.	Air resistance, sec. Tap
Kraft Pulps						
So. pine, Georgianier	47	62	130	147	13	47
So. pine, Georgianier[a]	54	74	144	154	17	57
So. pine, no. 2	42	51	111	121	22	28
So. pine, prehydr.	62	73	109	115	21	40
So. hardwood	24	40	65	95	8	27
N.E. softwoods	47	57	184	190	60	108
No. pine Kamyr	50	58	198	229	122	180
Western, no. 1	58	64	165	170	36	92
Western, no. 2	55	63	169	175	40	112
Sulfite Pulps						
So. pine	34	40	64	70	8	22
N.E. photo alpha	54	60	111	114	70	80
N.E. softwood no. 2	38	38	107	121	120	180
N.E. hardwood	20	20	14	17	3	7
N.W. hemlock	42	45	92	101	50	61
N.W. hemlock[a]	43	48	97	103	39	60
N.W. TAPPI Std.	32	33	85	93	48	56
N.W. acetate grade	55	52	64	66	11	13
Cotton linters, mod.	54	53	95	90	3	3

[a] Tests made at laboratory of Rayonier Inc., Jesup, Ga.

the group of sequestering agents. Other than this, there were no differences between anions on the basis of valence. Polyvalent cations, however, caused very rapid increase in beating time up to about 0.002 *N*, then little further increase. The specific point for tap water is shown on each of the generalized figures and falls about where it might be expected from the ionic content of this water.

The results found are in general agreement with the literature as to trends. Although the beatings were actually made in the presence of ions, results are similar to those found by addition of ions to pulp beaten in their absence (*6*). Also, results in the Valley beater, with rough bar surface, are comparable to those in the smooth-surfaced Lampen mill (*11–13*). It was therfore concluded that the ions have a direct effect only on the behavior of the fibers in water suspension, and not on some other function in the beating itself.

Yorston's mechanism (*2*) for electrolyte effects is fully supported by this work. While it was found that sheets could be cast in tap water without serious change in strength properties, the effects of electrolytes on freeness were very rapid. If freeness samples were prepared in a small amount of deionized water, then diluted to 1000 ml. with tap water and transferred at once to the freeness tester, freeness values were increased in proportion to the amount of tap water used.

Direct evidence of the effect on fibril dispersion was also found in the specific surface tests. A sample beaten in deionized water was brought to equilibrium in the test cylinder. It showed a normal slight decrease in flow rate as the fibers packed down. Aluminum chloride solution was introduced, and as this penetrated the pad the change in flow rate reversed to a visible increase within a few minutes. Conversely, an aluminum-treated sample showed greater than normal decrease in flow rate when Versene solution was added.

Softening or complexing agents in most cases sharply reduced the effect of cations on beating time (Table II),

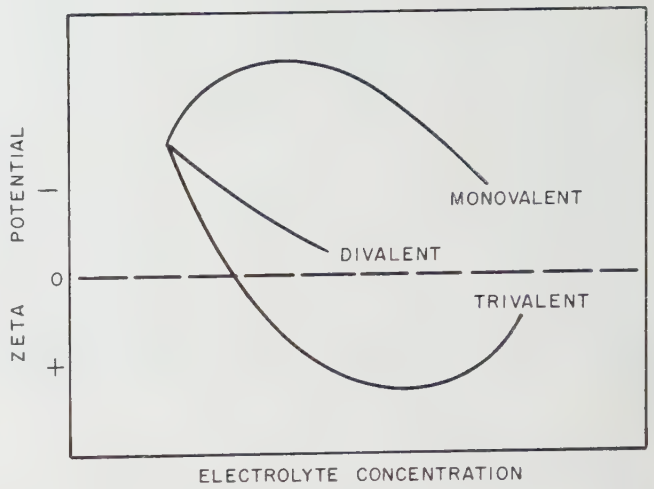

Fig. 8. Generalized relation between electrolyte concentration and zeta potential

burst, and air resistance. However, since these agents necessarily introduce other ions (normally sodium), they could never restore completely the conditions obtained in deionized water.

As was noted in the Australian work (*12, 13*) the handsheet test quality most responsive to electrolytes was the air resistance. Other tests were less responsive on either the constant freeness or constant time basis. On the constant time basis, differences among ionic types were small, as illustrated in Fig. 5. Their general form, however, agreed with the finding of Cohen and co-workers (*12*) as summarized by Emerton (*25*).

Some explanation of these observations is found in a striking and perhaps not too coincidental similarity which was noted between Fig. 5 and a diagram (Fig. 8) of the effect of electrolytes on zeta potential of colloidal surfaces (*26*). Addition of monovalent ions increases the zeta potential of fibers slightly. This could induce a greater dispersion of fibrils and, in a sheet of fibers laid down from this condition, would give a slightly more closed sheet with higher air resistance. Divalent ions have little effect or may slightly discharge the fibers, while trivalent ions quickly discharge them and may even reverse the charges with parallel effects on fiber dispersion. Effects on other sheet tests were smaller; in fact, as shown below, there appears to be little or no influence on bonding power.

There were, as noted, significant upward trends in burst (Fig. 4) and tensile on the constant freeness basis with added electrolyte, and some decrease in tear. All of these trends were consistent with those to be expected from the additional beating time needed to reach 400 C.S. freeness in the presence of electrolytes. At constant time, however, the picture was quite different. Although freeness tests showed a variation much like Fig. 2, other tests were much less affected (Fig. 5).

Variations of specific surface with added electrolytes were also in agreement with the cited mechanism. The surface determination actually measures only surfaces of channels open to water flow. Thus, if fibrils are permitted to draw together their effective surface decreases. Correlation of surface and freeness data, shown in Fig. 6, has a statistical coefficient of 0.92. For data from a variety of experiments, and in view of the assumptions of the method, this was considered

good. Corte (*21*) and Thode (*22*) have also shown these factors to correlate well.

It was therefore concluded that the effect of the electrolytes was primarily on the dispersion of the fibrils and fragments of fibers produced by beating. Electrolytes could affect the action of the beater bars on the fibers only if the slightly greater compactness of each fiber and its associated fibrils persisted through the turbulence of the beating area.

Sheet formation, at least in the hand mold, is slightly influenced as shown by air resistance data. Since this test also is based on fluid flow, the same explanations apply as for water flow. There was, however, much less effect on bonding of the fibers, as indicated by the smaller variations in strength.

Correlations between surface and strength have been studied (*20–22*) and found to be limited. A better agreement with strength is shown by specific volume. While there may be some effect of electrolytes on swollen volume, the present data were not sufficiently accurate to yield good volume figures. However, over the limited range of beating given to samples of Series 1 in Fig. 6, specific surface and burst strength were roughly correlated. They increased together in a manner shown by the "typical beater trend" in Fig. 7. Samples of Series 2, with constant beating time in various waters, showed no such relation. Thus it appeared that similar bonding power was developed by fibers with widely different amounts of surface. There was no strength advantage gained from the doubling of exposed surface brought about by beating in deionized water or by adding sequestrants, the means used to reach the higher values of specific surface. Or, since specific surface and freeness have shown good correlation, freeness is a poor guide to judging the burst strength to be expected from a beater test if water composition is variable. In comparisons between mills on different water supplies, or if seasonal variations in water hardness occur, results may be quite misleading when compared at equal freeness. A comparison at constant time should be more accurate, if the beaters are known to be in equal calibration. Since water composition would also affect calibration tests, these at least should be made in deionized water. Alternatively, the use of deionized or distilled water throughout the testing, as has been adopted in some countries already (*13–16*), would make all tests comparable and permit closer standardizing of the beater test generally.

A corollary precaution must also be taken in the calibration of freeness testers. Since different locations are commonly involved in this work, it would probably be better if deionized water were specified for this calibration.

Some of the literature cited has attributed the effects of electrolytes to certain groups or locations in the cellulose molecule. The comparison of pulp types was made partly to find any possible clue to this relation. As Table III shows, kraft pulps were generally susceptible to water composition, beating faster in deionized water. Most sulfite pulps showed less difference in beating rate and some none. As well as increasing the beating rate of nearly all samples, the deionized water gave weaker and more porous (less beaten) sheets at 400 C.S. freeness. The data recorded in Table III are extracted from test curves on each sample; peak values of the respective curves did not show such consistent results. Thus constant freeness is again a fallible guide for sample evaluation.

The TAPPI beater reference pulp showed very little difference in this comparison. This standard pulp was therefore a fortunate choice for interlaboratory testing, as the deviations due to water composition should be minimized.

Test values on these pulps were compared with analytical data on the same samples. Analyses examined included ash and its components, alpha-, beta-, and gamma-cellulose, carboxyl, viscosity, xylan and mannan by chromatography, and others. To date no correlation with any analytical criterion has been found. No conclusion, therefore, can be drawn that any specific group in the cellulose is concerned with the electrolyte effects. Actually, if the effects are entirely electrostatic no specific combination is necessary to the noted results. On the other hand, the general difference between kraft and sulfite fibers remains unexplained. Possibly it stems from structural differences caused by the cooking methods.

SUMMARY AND CONCLUSIONS

Examination of the effect of electrolytes on the Valley beater test was made using a bleached pine kraft pulp. Ionic materials caused an increase in beating time to reach a given freeness, polyvalent cations being much more effective than monovalent ones. Anion choice had little significance, except that sequestering agents could partially overcome metallic ions. The effects of the electrolyte were seen most strongly in the freeness test, notably also in air resistance, and to lesser degrees in burst, tensile, and other tests. All the changes, however, were those which would be normal for the longer time required to beat the pulp to a given freeness, and were much less notable at constant beating time. Changes in freeness also correlated well with the specific surface of the fiber slurries, but again strength tests did not.

The experiments support the mechanism of Yorston (*2*). The effects are concluded to be primarily electrostatic. The beating operation itself is not directly affected, but the dispersion of fine fragments and fibrils is influenced by the cations present. Such ions discharge or cancel the natural repellency of the fibrils and permit them to contract. This opens wider the passages between fibers and allows more flow through a network of fibers. There appears to be little effect, however, on bonding of the fibers to each other.

Consequently, freeness tests on pulps cabable of making especially strong sheets may vary up to 50% when the water composition changes. Constant freeness is therefore an undependable basis of comparison, especially for tests made at different locations or times. If deionized water were used as a beating and testing medium this difficulty could be avoided; otherwise, constant beating time should be a preferable basis of comparison. Calibration of the beater and the freeness tester with standard pulps should be done only with deionized water.

Kraft pulps are more susceptible in general to effects of electrolytes than are sulfite pulps. The TAPPI beater reference pulp, for instance, is relatively free of this hazard to interlaboratory testing. No relation

has been found between any analytical quality and the susceptibility to electrolytes.

Effects of electrolytes have been recognized in the standard pulp testing methods of several countries, but not yet by TAPPI. Appropriate changes or precautions should be recommended for TAPPI Methods.

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Received Oct. 9, 1959. Presented at the 10th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Portland, Ore., Aug. 17–21, 1959.

Contribution No. 49 from Olympic Research Division of Rayonier Incorporated.

Oxidation Lagoons

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After accomplishing all practical internal recovery methods and practicing settleable solids removal, there is present a quantity of dissolved organic matter in paper mill effluents. In some locations, it is necessary to remove a portion of this organic matter to reduce the B.O.D. load discharged. Destruction of this organic matter is accomplished by biological oxidation. Biological oxidation proceeds aerobically or anaerobically. All other factors being equal, biological oxidation proceeds at a greater rate in the presence of free oxygen or in the aerobic state. This fact has been borne out in laboratory tests and has been applied in the field to accomplish greater B.O.D. removals in a fixed period of time by the addition of air to oxidation lagoons. By seeding, the addition of air and nutrients decomposition rates in oxidation lagoons are increased and detention periods for treatment are reduced. The development of turbine type aerators that appear to be efficient aeration devices may make aeration of shallow lagoons feasible.

The reduction in organic loadings in process effluents prior to discharge into streams is becoming more prevalent. Increases in population and simultaneous industrial expansion have resulted in increased B.O.D. loads which, in some cases, cannot be assimilated in the stream. The paper industry has felt the need for stream improvement and taken tremendous strides in this direction.

Substantial reductions in the B.O.D. load of mill effluents has been accomplished by internal improvements. This improvement is particularly pronounced in the kraft industry and is shown in Fig. 1. With the advent of better washing systems, good water-re-use practices, and installation of recovery plants, the B.O.D. loads are now about $^1/_6$ what they were 20 to 25 years ago. Pronounced reductions in B.O.D. load are also accomplished where cooking liquors from the semi-chemical process are recovered. Other segments of the industry have not been so fortunate as to have a successful and economical liquor recovery system which might be almost universally employed to recover chemicals as well as reduce the B.O.D. load. The sulfite industry, however, has employed by product production, and other miscellaneous means to substantially reduce the B.O.D. load from this portion of the industry. The re-use of process waters and primary sedimentation have both contributed to a reduction in B.O.D. loads in other mill effluents.

Even with the best of internal recovery systems coupled with solids removal equipment, it is sometimes necessary to reduce the B.O.D. load in the mill effluent prior to discharge particularly during the periods of low stream flow. While controlled discharge and land disposal can sometimes be practiced, the bulk of the B.O.D. removed from mill effluents in the paper industry is accomplished by biological methods.

MECHANICS OF THE BIOLOGICAL PROCESS FOR B.O.D. REMOVAL

The use of a biological process to decompose organic matter involves utilizing bacteria and other micro-

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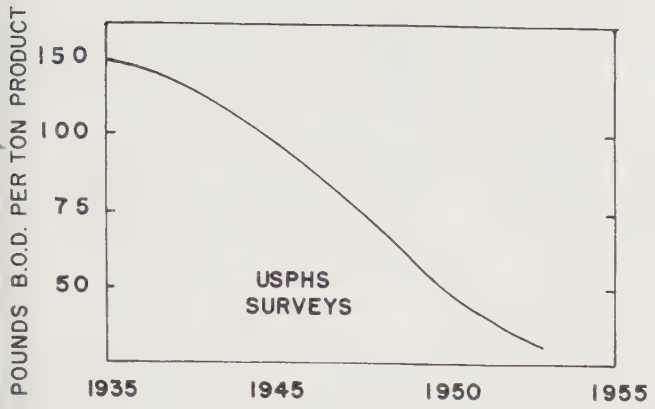

Fig. 1. Reduction in B.O.D. of kraft mill effluents effected by recovery plant improvements

organisms in the production of simpler compounds which are partially or completely resistant to further bacterial degradation. As bacterial decomposition proceeds, the amount of organic material is reduced, hence the B.O.D. is reduced and a more stable end product is the final result. The process of bacterial destruction of organic materials in waste treatment has, therefore, been correctly labeled, purification or stabilization.

When stabilization takes place in the presence of free oxygen or aerobic conditions, the end products are carbon dioxide, water, and oxidized inorganic compounds of principally sulfur and nitrogen. When decomposition proceeds in the absence of free oxygen or anaerobic conditions, the degree of purification is usually not so advanced as under aerobic conditions. The end products may be methane, partially degraded organic materials and reduced inorganic compounds composed principally of sulfur and nitrogen. Decomposition may be accomplished by facultative organisms at some phase between these two extremes in an atmosphere of reduced oxygen tension. Therefore, biological oxidation may proceed in the presence or absence of free oxygen.

The biological process of purification is not an instantaneous process and appreciable periods of time are required for stabilization. The time required is a function of a number of variables; among these being temperature, availability of a balanced nutritional media, number of organisms present, amount of oxygen available, and degree of stabilization required.

The rate at which B.O.D. is removed or biological decomposition is accomplished is a function of temperature. Within the limits of temperatures encountered in most waste streams, the rate of reaction increases about 4.7% per °C. rise in temperature or the reaction rate is increased slightly in excess of $1^1/_2$ times for each 10°C. rise in temperature.

To establish and maintain an active biological culture in addition to carbon, hydrogen and oxygen, at least *traces* of other elements must be available for bacterial assimilation. Among these trace elements are nitrogen, phosphorus, and potassium. Most paper mill effluents are almost devoid of nitrogen and most of the phosphorous, if present, has been added in process. Therefore, to sustain maximum biological activity in a treatment process, it is necessary to add nitrogen and phosporous to most paper mill effluents.

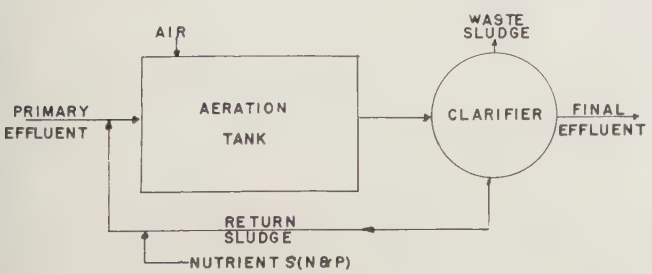

Fig. 2. Flow diagram conventional activated sludge

APPLICATION OF THE BIOLOGICAL PROCESS

Extensive use has been made of biological decomposition of organic material, in effluents from the paper industry, by the use of oxidation lagoons. In their simplest form, these lagoons are little more than storage basins where effluent is detained for periods usually considerably in excess of 10 days and as much as 60 to 80 days. Since conditions are essentially quiescent, oxygen transfer occurs only at the air-water interface. The limited oxygen supply available may allow aerobic, anaerobic, and some phase of decomposition between these two extremes to proceed in the same lagoon, depending on the depth of the pond, rate of oxidation, and influent B.O.D. concentrations.

With the use of adequate air, nutrients, and development of a floc of bacteria and other microorganisms, a high degree of B.O.D. removal is accomplished in relatively short periods by the activated sludge process. A flow diagram of a conventional activated sludge unit is shown in Fig. 2. After solids removal, the wastes are treated in an aeration tank containing the activated sludge. After suitable periods of aeration, usually 4 to 6 hr., the combination is settled in a secondary clarifier with all or a portion of the sludge being returned for seeding the incoming raw waste.

The activated sludge process has been investigated extensively as a method of treatment for a number of different mill effluents from the industry. A summary of the operating results is shown in Table I. B.O.D. removals of 60 to 97% were accomplished with aeration periods of 2 to 6 hr. being required. The data show that a number of paper mill effluents are capable of being biologically oxidized to a high degree by the activated sludge process.

Activated sludge and storage basins actually represent the two extremes in space required for B.O.D. removal treatment or detention time required for equivalent treatment. To obtain higher degrees of stabilization with reduced storage time, certain aspects of the activated sludge process have been implemented to increase the efficiency of oxidation lagoons. It has been shown that by increasing the microbial population present the B.O.D. removal rates are increased and equivalent B.O.D. reductions are obtained in shorter periods of storage. Moggio detected this increased rate of B.O.D. removal in extensive laboratory studies to evaluate the effects of seeding on stabilization of kraft mill effluents (*1*). Table II shows the oxidation obtained in effluent pilot operations where effluent from the activated sludge process was mixed with raw waste prior to storage. These data show the feasibility of supplementing treatment by storage with a small secondary treatment plant for seeding. B.O.D. removals of about 50%, obtained by storing a mixture of 1 part of treated effluent and 2 parts of raw waste for 5 days,

Table I. Summary of Results—Pilot Aeration Plants

Type of waste	Aeration tank details: Capacity, gal.	Aer. period, hr.	Daily vol., gal.	Aerator Suspended solids, p.p.m.	5 Day B.O.D. Load lb./1000, cu. ft./day	Reducn., %
Kraft, total effluent	12,600	3–6	40,000–80,000	1500–2500	100	90
Soda, diluted black liquor	1,230	4.2	4,300	1900	115	92
Sulfite, soda, old paper	3,750	2–6	12,300–33,000	3000	95	80–93
Neutral sulfite machine water	1,230	4–5	5,700	1500	72–150	60–83
Neutral sulfite machine water news and chip	317,000	6–9	750,000	1500–2000	45–58	75–90
Deinking	92,300	4	460,000	6800	750	73
Coated paper, broke wash	1,230	6	2,700	6900	68	97
Boardmill, settled white water	8,500	4	38,000	2000–3000	66	80–90
Domestic sewage		4–6		1000–2500	30–60	95

requires about 12 days storage to accomplish the same B.O.D. removal in a similar unseeded waste.

One of the more important factors, if not the most important single factor in achieving accelerated oxidation rates in the lagooning of mill effluents, is the maintenance of an adequate supply of oxygen in the effluent while in storage. This has been borne out in the laboratory on different mill effluents. Figure 3 is a plot of experimental work performed by Amberg to investigate the rate of stabilization obtained by recirculation with diffused air (*2*). The results show that over 90% B.O.D. reduction occurred in 4 days' storage in the aerated effluent while less than 40% B.O.D. reduction occurred in the unaerated effluent in 14 days' storage.

Table II. Effect of Aeration Treated Effluent on Storage Oxidation Rate

Ratio treated effluent/raw waste	Storage period, days	p.p.m. B.O.D. (5 day): Raw waste	Treated effluent	Mixture	p.p.m. removal: Treatment	Lagoon	Total
Waste alone	20	210	...	81	...	129	129
1:3	3	213	18	90	49	74	123
1:2	5	173	8	59	55	59	114

Figure 4 shows B.O.D. removals upon storage of a mill effluent at different depths. One can conclude from these data that stabilization occurred more rapidly at the shallow depths. This is explained by the limited amount of oxygen supplied by surface absorption in the deep samples. As the area exposed becomes greater in relation to the total volume, oxidation rates increase.

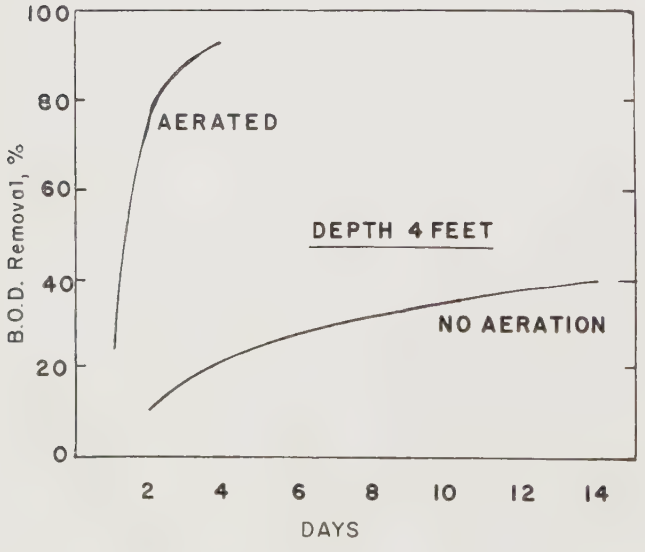

Fig. 3. Effect of aeration on storage stabilization

These laboratory results have led to testing and application of oxidation lagoons in the form of aerated stabilization basins for treatment of paper mill effluents. The results from two pilot installations and two full scale applications are shown in Table III. The first installation is a pilot installation holding 200,000 gallons and treating white waters together with rag and flax cooking liquors. This waste is weak, ranging from 47 to 125 p.p.m. in B.O.D. and is cold, since well water is employed in the mill and machine water is not heated. The waste was substantially neutral and sufficient phosphorus and nitrogen was added to insure against a deficiency of these elements becoming a limiting factor in microbial activity. The basin was seeded with activated sludge from a neighboring sewage treatment plant and a portion of the effluent recycled to sustain the seeding effect. Despite the low temperature (13 to 16°C.), and the short detention period (1 day), a consistent B.O.D. reduction of 45% was observed over a $2^1/_2$-month test period.

The second installation consists of a pilot basin 10 ft. deep, and has a capacity of about 100,000 gallons. It is equipped with an air header running across the basin, with sparger type diffusion nozzles attached to it. The wastes consist of a settled mixture of kraft pulping effluent, deinking washer water, bleachery wastes, and white waters, and has an initial B.O.D. in the 300 p.p.m. range. Nitrogen and phosphorus are added and automatic neutralization is provided to prevent the presence of caustic alkalinity in the influent.

Recirculation has been provided for but does not appear necessary owing to the degree of mixing and the detention periods employed (3 to 4 days). The waste

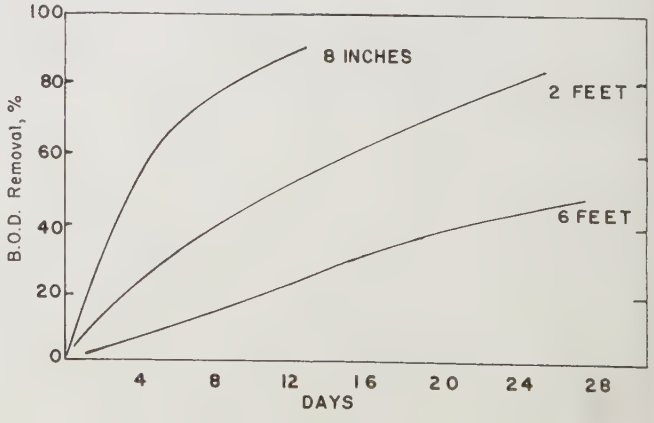

Fig. 4. Effect of depth on storage and oxidation

Table III. Performance of Aerated and Recycled Stabilization Basins

Installation no.	Type of waste	Depth, ft.	Definition, days	Air cu. ft. gal.	Recycled, %	Temp., °C.	Av. B.O.D.-p.p.m. Influent	Effluent	Remaining	Reduction, %
1	Flax pulp w. water	6	1	0.75	20	13–16	73	40	33	45
2	Int. kraft	10	4	1.35	0	20–36	252	89	163	64
2	" "	10	4	1.93	0	26–39	213	40	173	81
2	" "	10	3	1.80	0	26–40	193	52	141	73
3	News- chip	5	9	0	16x	Win.	533	240	293	55
3	" "	5	9	0	16x	Spr.	542	208	334	62
3	" "	5	9	0	16x	Sum.	515	110	405	78
4	News-chip	4–5	10	1.00	0	87–64	378	122	256	68

has a temperature of 35 to 40°C., but cools quite rapidly in the basin during the winter months. Data presented in the figure indicate a B.O.D. reduction of 81% at 4 days' retention during warm weather when the waste retained in the basin did not drop below 26°C. and the air rate was high. A reduction in holding time to 3 days dropped the B.O.D. reduction to 73%. When the temperature dropped to the 20°C. range, reduction dropped to 64% in 4 days.

Installation no. 3 is a full-scale unit treating 0.5 MGD of settled news and chip effluent. The basin employed is 5 ft. deep and provides a displacement detention period of 10 days. This basin is not aerated, but the contents are recycled at 16 times the waste-flow rate by means of low head-pumps which return waste from the discharge end to riffles at the head end of the unit. Nutrients are not used in this flow which has a B.O.D. in excess of 500 p.p.m. As shown by the data presented, a 55% B.O.D. reduction occurs during the winter months, a 62% reduction in the in-between seasons and a 78% reduction during the summer.

The fourth stabilization basin is also a full-scale job, treating settled news and chip effluent. The B.O.D. of the raw waste averaged 378 p.p.m. and no nutrients are added, although sodium nitrate is used periodically for odor control. No recirculation is practiced. About 4.3 MGD are treated and air is supplied by means of diffusers. The waste being quite hot, maintains fairly high basin temperatures. During the short period of operation for which data are available, this basin has produced a B.O.D. reduction of 68%.

Other investigations are under study employing the principle of aerated stabilization basins for B.O.D. removal. The experience to date shows that aeration by diffused air or recycling improves oxygen transfer thereby increasing the degree of stabilization. The air requirements based on these studies appear to be in the same range as those required for activated sludge.

The addition of air, or method chosen to transfer oxygen to the liquid media in lagoons, would appear to depend on the configuration of the lagoon and the ability of the diffusing device to operate without plugging. One must consider adequate mixing to assure a uniform oxygen gradient in the lagoon as well as the oxygen transfer efficiency of the method chosen. Some existing aeration devices are capable of high efficiency oxygen transfer but would effect little mixing or cycling of basin contents to assure distribution of the aerated mixture and development of new air-water interface at the surface. The use of a turbine type mechanical aerator which entraps air by creating a violent churning action and vortex flow is under investigation. This equipment, in addition to aerating, also acts as a pump and accomplishes some degree of mixing of the basin contents. The equipment appears to be well adapted to existing lagoons of shallow depth where oxygen transfer by diffused air is poor and mixing, to assure uniform oxygen distribution, is difficult. The power requirements reported for the absorption of a pound of oxygen indicate the unit to be an efficient aeration device.

The simplest method of aeration is that provided by taking advantage of natural features to induce riffling or aeration by flowage in ditches. Table IV shows the B.O.D. reduction obtained by combining storage with flow in open ditches prior to discharge into the receiving stream and also the reduction in B.O.D. accomplished during transport of a mill effluent when mixed and not mixed with the receiving stream. The B.O.D. reduction accomplished by flowage after storing may well be partially chemical oxidation of reduced compounds produced by anaerobic decomposition.

Table IV. Oxidation of Kraft Mill Effluents on Flowage
(Approximately 7 miles flowage)

Mill No.			Effluent B.O.D.	Outfall B.O.D.	Reduction, %
1	Flowage and storage	Max.	293	48	
		Min.	82	7	83
		Av.	147	19	
2	Flowage alone	Max.	133	63	
		Min.	50	49	65
		Av.	97	34	
3		Max.[a]	62	38	
		Min.	24	9	40
		Av.	44	27	
4	Storage and flowage	Max.	111	20	
		Min.	97	1.2	99
		Av.	104	1.3	

[a] Effluent mixed with stream.

SUMMARY

Laboratory and field tests have shown that the use of oxidation lagoons is one approach to stabilization of mill effluents prior to discharge. Biological oxidation accomplishes the destruction of organic matter with the possibility that some chemical oxidation may take place upon aeration of the contents of lagoons that have been under anaerobic conditions. In their simplest form, oxidation lagoons are simple natural or man-made storage basins. These basins being essentially quiescent absorb oxygen at the air water interface.

The amount of oxygen that can be transferred to the surface in quiescent storage is limited, which may result in aerobic conditions existing at the surface only, if at all. Decomposition of organic matter or stabilization is then accomplished in the anaerobic state or at reduced oxygen tension by facultative organisms. All other factors being equal, the rate of decomposition of paper mill effluents is slower under anaerobic conditions

than under aerobic conditions. In addition, the production of malodorous compounds may be experienced with a number of mill effluents if an adequate supply of oxygen is not present. More oxygen transfer by surface re-aeration per unit of volume can be obtained by storing at shallow depths, preferably 3 ft. or less. Whether aerobic conditions are maintained in a storage lagoon where supplemental aeration is not provided will depend on the B.O.D. load applied, the rate of oxidation of the organic matter, and the surface area exposed. Most oxidation lagoons exhibit some degree of anaerobiosity if supplemental oxygen is not provided.

Laboratory and field tests have shown that the rate of B.O.D. removal can be improved by maintaining sufficient nutrient concentrations in the form of nitrogen and phosphorus to sustain maximum biological activity. Seeding, the introduction and maintenance of an increased amount of suitable micro flora and micro fauna, in addition to that present and developed naturally, has been shown to increase B.O.D. removal rates.

The introduction of free oxygen either by natural means as in riffling or by mechanical means as with diffuser or turbine aerators will increase oxidation rates and achieve more B.O.D. reduction per unit of time. The addition of sufficient oxygen will assure aerobic conditions and hence eliminate the production of malodorous compounds that are associated with anaerobic decomposition of some mill effluents upon storage.

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Received Oct. 30, 1959. Presented at the 14th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Pittsburgh, Pa., Oct. 12–15, 1959.

Patterns of Circumferential Flow in Annuli

A. H. NISSAN and F. C. HAAS

A review of circumferential fluid motion in an annulus is presented. Flow caused by rotation of either confining wall, pumping, or a combination of wall rotation and pumping is illustrated. A qualitative description of these types of flow is given and the method of quantitatively predicting the point of laminar critical flow is described.

If the available solutions of the Navier-Stokes equations for flow in an annulus are considered, they are found to be valid, in general, only for relatively small fluid velocities. When a certain "critical" velocity is exceeded the flow pattern obtained by the linearized solution of the Navier-Stokes equations becomes unstable and breaks down. The fluid motion may become random as in turbulent motion or it may become characterized by a laminar pattern different from the original pattern. In either case the definition of fluid stability is violated. The point of neutral fluid stability may be defined as that point beyond which a perturbation of the streamlines causes the resultant steady state fluid motion to be different from the original steady state motion.

Circumferential flow in annuli may be produced by rotation of either confining cylinder, by flow under a pressure gradient in a curved passage, or by combination of the above mentioned means. In this paper the authors summarize the work done to date, present a qualitative description of the flow patterns possible, and discuss the criteria for the onset of certain three-dimensional flow patterns which are characteristic of such systems once these criteria are exceeded.

The following physical laws must be obeyed when a homogenous fluid is in motion in any type of conduit:

1. There is no slip of the boundary layer at stationary surfaces under ordinary conditions (gases at ordinary pressures). In other words, all particles of fluid in contact with a moving surface move with the velocity of that surface.
2. The velocity distribution of a moving fluid is a continuous function of space coordinates.
3. The laws of continuity of mass and energy apply.

By application of these fundamental principles, it is possible to establish qualitatively the fluid velocity distribution in a conduit without elaborate mathematical treatment.

Limiting ourselves to flow in an annulus, once the velocity distribution has been qualitatively predicted, the regions of flow which are potentially unstable may be predicted by applying the principle put forth by Lord Rayleigh (*1*) in 1916. Rayleigh considered a nonviscous revolving fluid and proposed that a fluid equilibrium was stable only if the square of the circulation monotonically increased outwards. Circulation, k, for a fluid in circular motion is proportional to the product of u and r. Von Kármán (*2*) in 1934 used a different approach to the problem but concluded that Rayleigh's principle was correct, while Synge (*3*) in 1938 extended the principle to include viscous fluids.

NOMENCLATURE

a = outside radius of inner cylinder, ft.
b = inside radius of outer cylinder, ft.
d = annulus width (b–a), ft.
d' = depth of liquid above inner cylinder, ft.
D = diameter, ft.
F_g = geometrical factor
h = heat transfer coefficient, B.t.u./hr., sq. ft., °F.
k = thermal conductivity, B.t.u./hr., sq. ft., °F./ft.
P = pressure
Q = volumetric flow rate through pump, cu. ft./sec.
r = radius, ft.
t = annulus length, ft.
u = circumferential velocity, ft./sec.
$\overline{V}$ = average fluid velocity, ft./sec.
δ = width of unstable region, ft.
θ = angle, radians
μ = ratio of the angular velocity of the outer cylinder to the angular velocity of the inner cylinder

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Subscripts

ν = kinematic viscosity, sq. ft./sec.
ρ = density, lb./cu. ft.
$\bar{\omega}$ = angular velocity, rad./sec.
0 = zero velocity
1 = pertaining to inside cylinder
2 = pertaining to outside cylinder
c = pertaining to criticality

DISCUSSION OF CRITICAL FLOW

Where the fluid motion is caused by rotation of one or both of the confining cylinders, the continuity equations may be simplified to:

$$\frac{\partial^2 u}{\partial r^2} + \frac{1}{r}\frac{\partial u}{\partial r} - \frac{u}{r^2} = 0 \qquad (1)$$

The solution of this equation is of the form:

$$u = Ar + (B/r) \qquad (2)$$

The constants A and B may be evaluated by considering the boundary conditions:

$$\begin{aligned} u &= \omega_1 a \quad \text{when } r = a \\ u &= \bar{\omega}_2 b \quad \text{when } r = b \end{aligned} \qquad (2a)$$

Making suitable substitutions the constants are evaluated as:

$$A = \frac{b^2\bar{\omega}_2 - a^2\bar{\omega}_1}{b^2 - a^2}$$

$$B = \frac{b^2a^2(\bar{\omega}_1 - \bar{\omega}_2)}{b^2 - a^2} \qquad (3)$$

Equation (2) is commonly called the Couette flow equation and the resulting primary flow pattern is known as Couette flow.

This primary flow will provide a circulation proportional to $Ar^2 + B$. Applying Rayleigh's principle of stability, if a region of this primary pattern is found to be unstable, the fluid elements containing the higher circulation will tend to move outwards and rearrange themselves in a stable arrangement. The rearrangement of fluid elements will be retarded by the viscous forces of the fluid. If the viscous forces are unable to retard the movement, the moving solid surfaces will tend to reestablish the Couette flow distribution, while the unstable fluid elements are tending to become stabilized, therefore a steady state secondary motion is produced. This motion, by no means random, will be spoken of as laminar critical flow.

Criteria for Neutral Stability

Couette flow received the first successful treatment of the theory on hydrodynamic stability. G. I. Taylor (*4*) in 1923, through an elaborate mathematical analysis, predicted the point of instability for Couette flow. He demonstrated his theoretical predictions by experiment and since then many workers have verified his classical theoretical and experimental work. His attack of the problem is the only general analysis available to date.

Taylor shows that when fluid motion is produced by rotation of the inner cylinder, the critical angular velocity is given by:

$$\frac{\bar{\omega}_c^2 a^2 d^3}{{}^1/_2(a+b)\nu^2} = \frac{\pi^4 f}{0.0571f^2 + 0.00056} \qquad (4)$$

where $f = 1 - 0.652d/a$. All mathematical treatments have been on systems where the gap width is small compared to the mean radius. Making this assumption

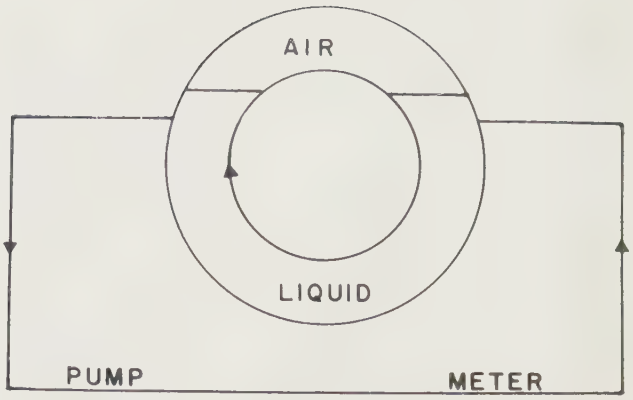

Fig. 1. Diagram of system under discussion

equation (4) may be rewritten in terms of a Reynolds number based on the gap width, d, and a dimensionless geometrical factor; the product being called the Taylor number.

$$Ta_c = \frac{\bar{\omega}_c a d}{\nu}\sqrt{d/a} = 41.2 \qquad (5)$$

Kaye and Elgar (*5*) present a geometrical factor, F_g, which corrects equation (5) for the finite gap width.

$$F_g = \frac{\pi^2}{41.2}\left[1 - \frac{d}{(a+b)}\right]^{-1} Z^{-1/2} \qquad (6)$$

$$Z = 0.0571\left[1 - 0.652\left(\frac{2d/(a+b)}{1 - [d/(a+b)]}\right)\right] + 0.00056\left[1 - 0.652\left(\frac{2d/(a+b)}{1 - [d/(a+b)]}\right)\right]^{-1} \qquad (6a)$$

In 1928 Dean (*6*) considered theoretically the flow in an annulus due to a circumferential pressure gradient. His analysis predicts an unstable cellular motion similar to Taylor's; the condition of criticallity being given by a dimensionless number similar to Taylor's except that the constant is changed:

$$\frac{\bar{V}_c d}{\nu}\sqrt{\frac{d}{a}} = 36 \qquad (7)$$

$\bar{V}$ represents the average velocity of the fluid in the annulus. Brewster, Grosberg, and Nissan (*7*) in 1959

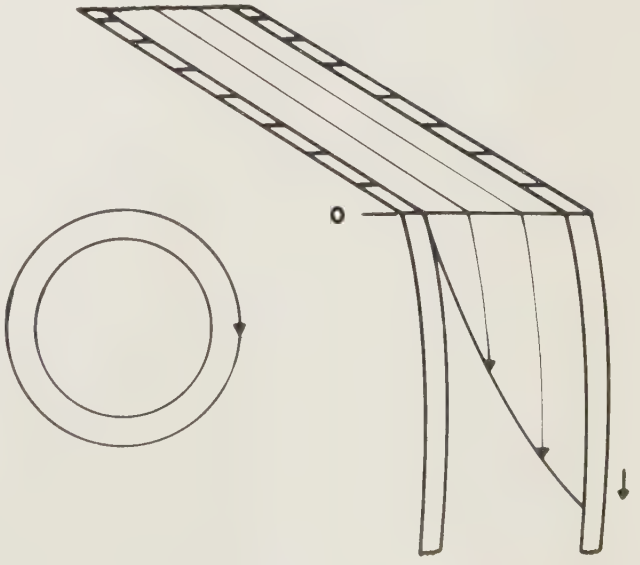

Fig. 2. Fluid motion with outside cylinder rotating

confirmed Dean's theoretical work with experimental observation.

Brewster, Grosberg, and Nissan (*7*) also present a theoretical and experimental analysis of the system where motion is produced by rotation of the inner cylinder while the flow is forced to reverse by means of a free surface. The condition of criticallity in terms of the dimensionless Taylor number is given as:

$$\frac{\bar{\omega}_c a d}{\nu}\sqrt{\frac{\bar{d}}{\bar{a}}} \cong 140 \qquad (8)$$

These workers also have considered the generalized case where the fluid motion may be due to rotation of the inner cylinder and simultaneous circumferential pumping. The ratio of the velocity due to rotation to the velocity due to circumferential pressure gradient is denoted by N.

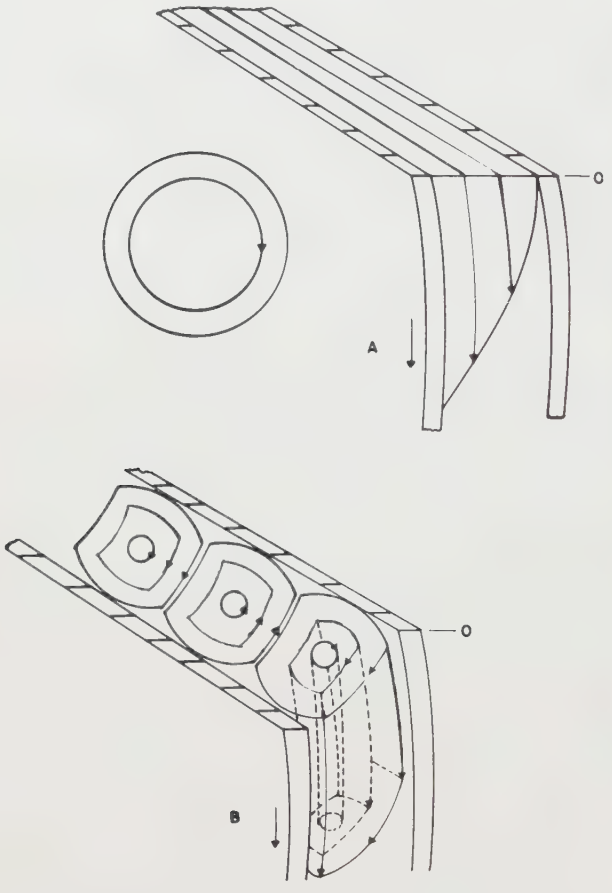

Fig. 3. Fluid motion with inside cylinder rotating

$$N = \frac{\bar{\omega}_1 a d t}{2Q} \qquad (9)$$

Q represents the volumetric flow rate through the pump. The system being considered may be visualized as shown in Fig. 1. Under the conditions imposed in this generalized case, the region of instability, δ, may or may not extend over the entire width of the gap. The parameter P is a dimensionless number based on the unstable region (not on the whole gap width) found useful in representing circumferential fluid motion:

$$P = \frac{\bar{V}\delta}{\nu}\sqrt{\frac{\bar{\delta}}{a}} \qquad (10)$$

The condition of neutral stability, i.e., when P reaches a critical value, P_c, is now dependent on δ and P, as follows:

$$0 < \delta/d < 2/3 \qquad P_c = 12$$

$$2/3 \leqq \delta/d \leq 1.0 \qquad P_c = 20.7\,(\delta/d)^{5/2}\sqrt{\frac{2\delta/d - 1}{(2\delta/d - 1)^2 - 0.01}} \qquad (10a)$$

The general parameter P, as will be shown later, may be made to include the particular problems considered by Taylor (*4*) and by Dean (*6*).

Rotation of Outer Cylinder Alone

Rotation of the outer cylinder with a stationary inner cylinder produces a flow which obeys the following Couette equation:

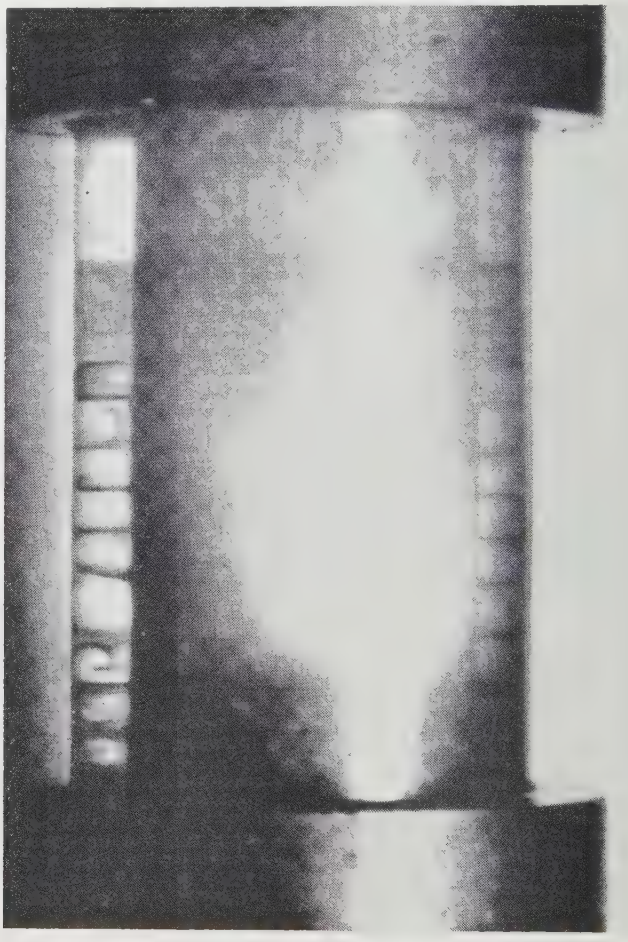

Fig. 4. Photograph of vortices obtained with inner cylinder rotating [after Taylor (4)]

$$u = \frac{b^2\bar{\omega}_2}{b^2 - a^2}\,r - \frac{b^2 a^2 \bar{\omega}_2}{r(b^2 - a^2)} \qquad (11)$$

This flow distribution as shown in Fig. 2 yields no region of potential instability when considered under the principles of Rayleigh. Taylor (*8*) has shown experimentally that such flow is free from instabilities to very high values of the Taylor number. The flow pattern will eventually break down, but the resultant pattern is a random turbulence rather than a steady type of laminar flow. The streamline motion as shown in Fig. 2 is of the "sliding lamina" type motion which is ordinarily associated with streamline or boundary layer motion.

Rotation of Inner Cylinder Alone

When flow is produced by rotation of the inner cylinder while the outer cylinder is at rest, the Couette equation takes the form:

$$u = \frac{b^2a^2\bar{\omega}_1}{r(b^2 - a^2)} - \frac{a^2\bar{\omega}_1 r}{b^2 - a^2} \qquad (12)$$

This primary flow distribution, illustrated in Fig. 3A, yields a situation where the entire gap width is potentially unstable ($\delta = d$). The streamline motion is once again of the "sliding lamina" type. The point of instability may be predicted by the Taylor equation (5) or it may be recognized that for this particular case $\delta/d = 1$, $N = 1$, and therefore equation (10) may be written as:

$$P_c = 20.6 = \frac{\bar{\omega}_{1c}ad}{2\nu}\sqrt{d/a} \qquad (13)$$

At the point of instability the flow no longer consists of sheets of fluid sliding over each other as they do in streamline flow. Instead the fluid motion consists of the steady secondary cellular type illustrated in Fig. 3B. The primary motion of the fluid is still in the circumferential direction of $\bar{\omega}_1$, but in the axial direction a cellular pattern occurs in which alternate toroidal cells rotate in opposite directions. These cells having been predicted and observed by Taylor in 1923 have since then come to be known as Taylor vortices. Figure 4 is a photograph of vortices obtained experimentally by Taylor. The vortex spacing as predicted by Taylor is equal to the gap width, i.e., the vortex occupies the area of a square with side equal to the annulus width.

The transition to turbulent flow by increasing the rotation of the inner cylinder is very slow. Several authors (*9–11*) have shown that the cellular pattern persists to a certain degree at Taylor numbers of several hundred times the critical value. Pai (*9*) has shown experimentally that the vortices persist at Taylor numbers of 100 to 200 times the critical value and that the cellular motion is more widely spaced, i.e., the vortices are distorted, elongated, and surrounded by random motion. At Taylor numbers above 200 times the critical value, Pai (*9*) reports that the Taylor instability is no longer recognizable and a general turbulence sets in.

Rotation of Both Cylinders

When the fluid motion occurs owing to rotation of both cylinders, one of several situations may occur depending on the relative speed and direction of rotation of the cylinders. If the cylinders rotate in the same direction, such that $\mu \geq 1$, it can be shown that the Couette distribution (equations 2 and 3) yields a situation similar to that illustrated in Fig. 2. There occurs no region of potential instability. If the cylinders rotate in the same direction with $\mu < 1$ the Couette equations (2 and 3) yield a situation similar to that illustrated in Fig. 3A except that both cylinders now have a finite velocity. The entire gap width is potentially unstable and following the approximation suggested by Di Prima (*12*) and Lin (*13*) the critical value of the Taylor number or the parameter P ($\delta/d = 1$) may be approximated by substitution of an arithmetic average velocity if the gap width is small.

If the cylinders rotate in opposite directions the streamline flow distribution as predicted by the Couette equations (2 and 3) is of the shape shown in Fig. 5A. To maintain a continuity of flow the streamline velocity at each boundary must be the same as the velocity of the cylinder, therefore there must be an intermediate point at which the fluid streamline has zero velocity. From Fig. 5A it may be noted that the inner region of flow is potentially unstable while the outer region is potentially stable, the line of demarcation being the streamline of zero velocity. The region of instability, δ, may be calculated by considering the radius of the zero velocity streamline as calculated from the Couette flow equation.

$$r_0^2 = \frac{(1 - \mu)(b^2 - a^2)}{[1 - (a/b)^2][1 - \mu(b/a)^2]} \qquad (14)$$

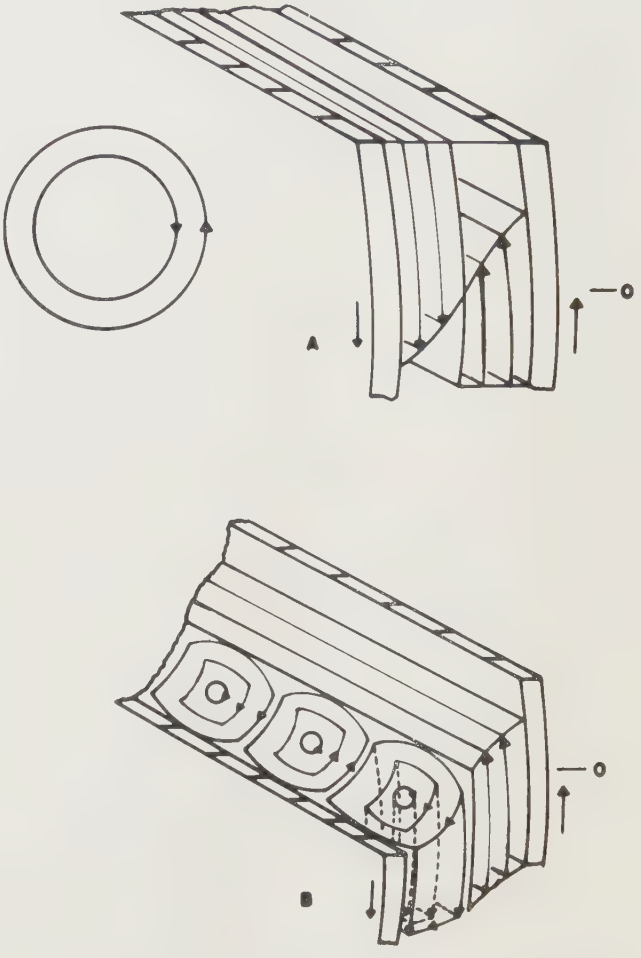

Fig. 5. Fluid motion with both cylinders rotating

Using equations (10) and (10a), the critical inner cylinder angular velocity for a given μ may be calculated:

$$P_c = \frac{\bar{\omega}_{1c}a\delta}{2\nu}\sqrt{\delta/a} \qquad (15)$$

The laminar pattern at critical flow is illustrated in Fig. 5B. The potentially unstable region has undertaken a cellular type motion similar to that described before, while the potentially stable region continues in the "sliding lamina" type of motion.

Pumping of Fluid in a Curved Passage

When the circumferential flow is due to a pressure gradient alone, the velocity at both cylinders is obviously zero. The primary velocity distribution may be approximated as:

$$u = \frac{1}{2\nu\rho a}(r - a)(r - b)\frac{d\bar{P}}{d\theta} \qquad (16)$$

or more accurately as given by Goldstein (*14*):

$$u = -\frac{1}{2\nu\rho}\frac{d\bar{P}}{d\theta}\left[\frac{rb^2 \log (b - a)^2 \log a}{b^2 - a^2} - \frac{a^2b^2}{(b^2 - a^2)r}\log\frac{b}{a} - r \log r\right] \qquad (16a)$$

The primary flow distribution has its maximum velocity displaced from the center toward the outside cylinder as the ratio d/a is increased. The streamline or "sliding lamina" of motion is illustrated in Fig. 6A.

$$\frac{\bar{V}_c\delta}{\nu}\sqrt{\frac{\delta}{a}} = 12.0 \qquad (17)$$

The type of fluid motion above the critical point is illustrated in Fig. 6B. The inner half of the gap continues in "sliding lamina" type motion while the outer half contains a cellular motion similar to that described before.

Simultaneous Rotation of Inner Cylinder and Circumferential Pressure Gradient

If the rotation of the inner cylinder occurs in direction opposite to the direction of pumping, the resulting flow distribution may be computed by adding vectorially the components due to Couette flow (equations 2 and 3) and those due to a pressure gradient (equation 16 or 16a). The resulting distribution may be similar to that shown in Fig. 7A. The distribution as shown

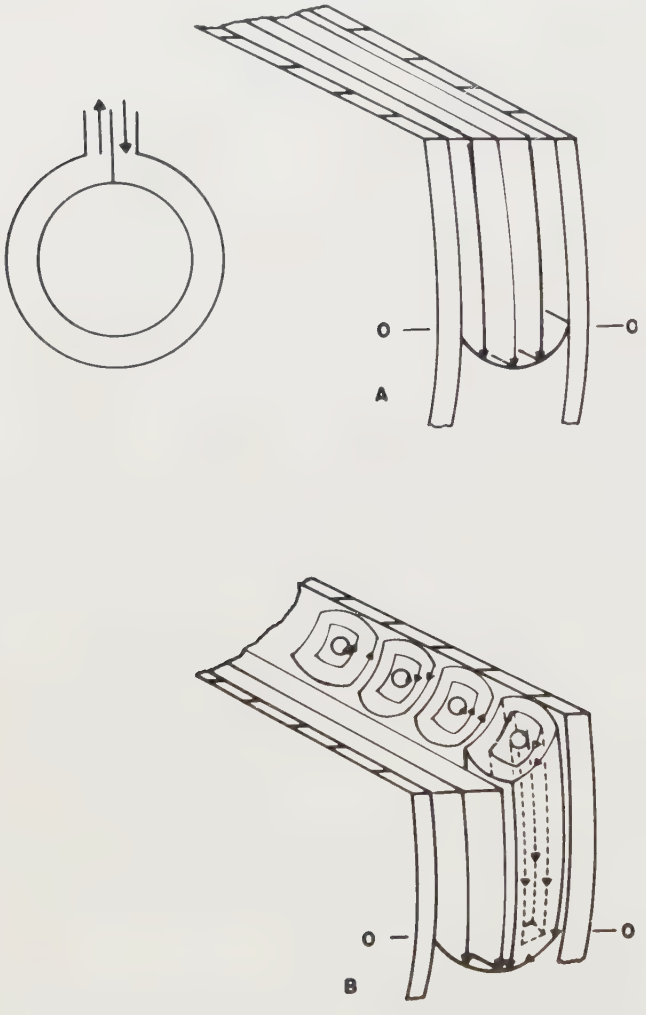

Fig. 6. Fluid motion with pumping in the annulus

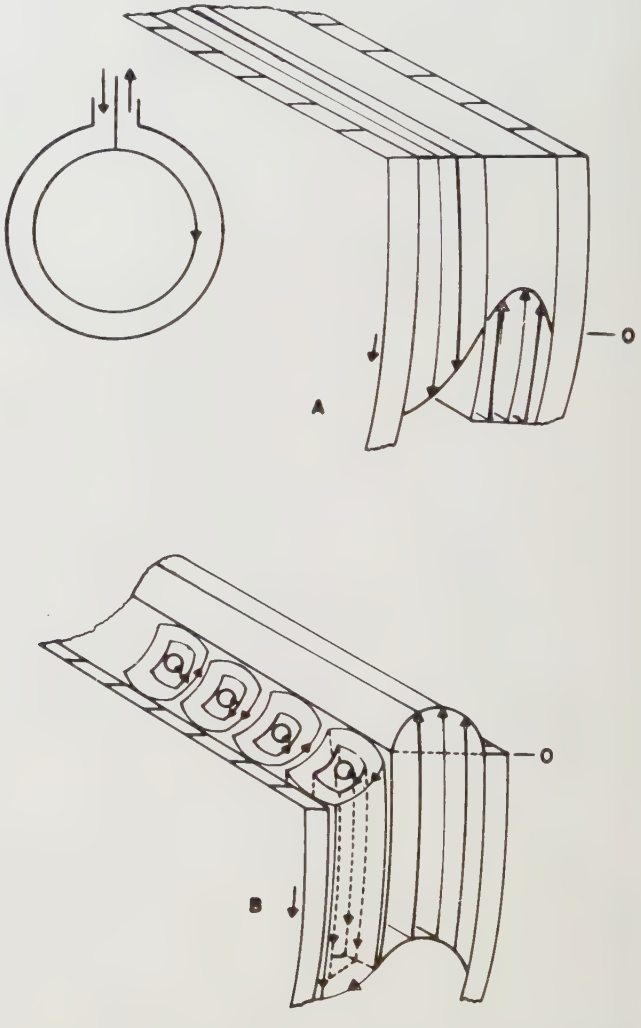

Fig. 7. Fluid motion with pumping opposite to rotation of inner cylinder

Figure 6A indicates that the region near the outer cylinder is potentially unstable when judged by Rayleigh's criterion. The point of neutral stability has been predicted by Dean (*6*) in equation (7). For a small gap width, $\delta/d = 0.5$ and by considering $N = 0$, the parameter P also defines the critical velocity, i.e.,

contains two regions of potential instability, one adjacent to the inner cylinder and one adjacent to the outer cylinder. Brewster, Grosberg, and Nissan (*7*) state that the region adjacent to the *inner* cylinder becomes unstable first if $-5.37 \geq N \geq \infty$ and that the *outer* region becomes unstable first if $0 > N > -5.37$. The point of first instability is defined as the point of

neutral stability. The values of δ/d and $\bar{V}$ to be used in conjunction with equations (10) and (10a) are listed in Table I (*17*). The flow pattern above the critical point is shown in Fig. 7B. The streamline motion persists in the stable region while the unstable region attains a steady cellular motion.

Table I. Defined Parameters for Various Values of *N*

Range	*Unstable region*	δ/d	$\bar{V}$
$0 > N > -5.37$	Outer	$\frac{2N-3}{6(N-1)}$	$\frac{\bar{\omega}_1 a(2N-3)^2}{18N(N-1)}$
$-5.37 > N > -\infty$	Inner	$\frac{N}{3(N-1)}$	$\frac{\bar{\omega}_1 a(8N-9)}{18(N-1)}$

If the rotation of the inner cylinder occurs in the same direction as the pumping, the primary fluid motion may again be obtained by vectorially adding the components corresponding to each type of flow, as mentioned before. The streamline motion is shown in Fig. 8A. The regions of potential instability are dependent upon the relative magnitudes of the pumping and rotational vectors. The flow defined by $0 < N < 0.75$ yields a profile with a maximum between $0 < \delta/d < 0.5$, indicating but one region of instability. The flow defined by $0.75 \leq N \leq 1.5$ yields a velocity distribution such that the entire gap width is unstable ($\delta/d = 1.0$); while for the flow where $N > 1.5$ the velocity distribution is such that two regions of potential instability occur. One region occurs adjacent to the inner cylinder while another occurs adjacent to the outer cylinder It has been shown (*7*) that the region adjacent to the inner cylinder will become unstable first and this point is again called the point of neutral stability. The values of δ/d and $\bar{V}$ to be used in equations (10) and (10a) are listed in Table II (*17*).

Table II. Defined Parameters for Various Values of *N*

Range	*Unstable region*	δ/d	$\bar{V}$
$0 < N < 0.75$	Outer	$\frac{2N-3}{6(N-1)}$	$\frac{\bar{\omega}_1 a(2N-3)^2}{18N(N-1)}$
$0.75 \leq N \leq 1.5$	Whole width	1.0	$\frac{\bar{\omega}_1 a}{2N}$
$1.5 < N \leq \infty$	Inner	$\frac{N}{3(N-1)}$	$\frac{\bar{\omega}_1 a\,(8N-9)}{18(N-1)}$

The fluid motion at the critical point for the flow of $0 < N < 0.75$ is shown in Fig. 8B. The inner stable region continues in streamline flow while the outer unstable region attains a cellular pattern again.

Rotation of Inner Cylinder with Reverse Flow

Fluid motion due to rotation of the inner cylinder with reversed flow may be accomplished in two ways. A barrier may be placed in the gap forcing the fluid to reverse direction, or the fluid may be drained to such a level that the uppermost inner cylinder surface is free of fluid. The streamline velocity distribution is given by:

$$u = \frac{(b-r)\bar{\omega}_1 a}{d} - \frac{(r-a)[d-(r-a)]}{2\nu\rho a}\frac{d\bar{P}}{d\theta} \qquad (18)$$

The streamline velocity profile is shown in Fig. 9A. Brewster and Nissan (*15*) show that the streamline of zero velocity occurs at a distance of one-third the gap width from the inner cylinder. Once again there exist two regions of potential instability. By considering the continuity of flow it may be shown that the potentially unstable region adjacent to the inner cylinder will become unstable first. This fluid pattern corresponds to a flow of $N = \pm\infty$ and by using $\delta/d = 1/3$, the critical angular velocity may be defined by:

$$\frac{\bar{\omega}_{1c} a\delta}{2\nu}\sqrt{\frac{\delta}{a}} = 12.0 \qquad (19)$$

The cellular motion attained above criticallity is shown

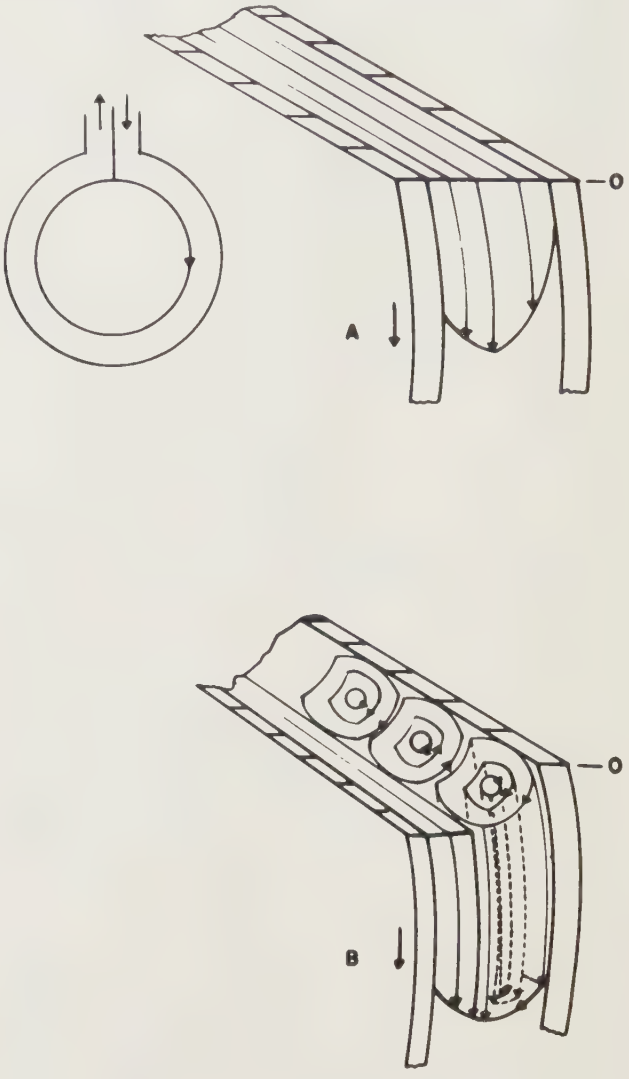

Fig. 8. Fluid motion with pumping in the same direction as rotation of inner cylinder

in Fig. 9B. The cellular motion occurs in the region adjacent to the inner cylinder and has a width of $d/3$. The outer two-thirds of the gap width maintains the streamline type of motion. Figure 10 is a photograph obtained by Brewster, *et al.*, for the system of fully reversed flow.

Rotation of Inner Cylinder with Partially Reversed Flow

When the fluid motion due to rotation of the inner cylinder is partially obstructed by a barrier extending only partially across the gap or by an interface occurring above the uppermost surface of the inner cylinder, a

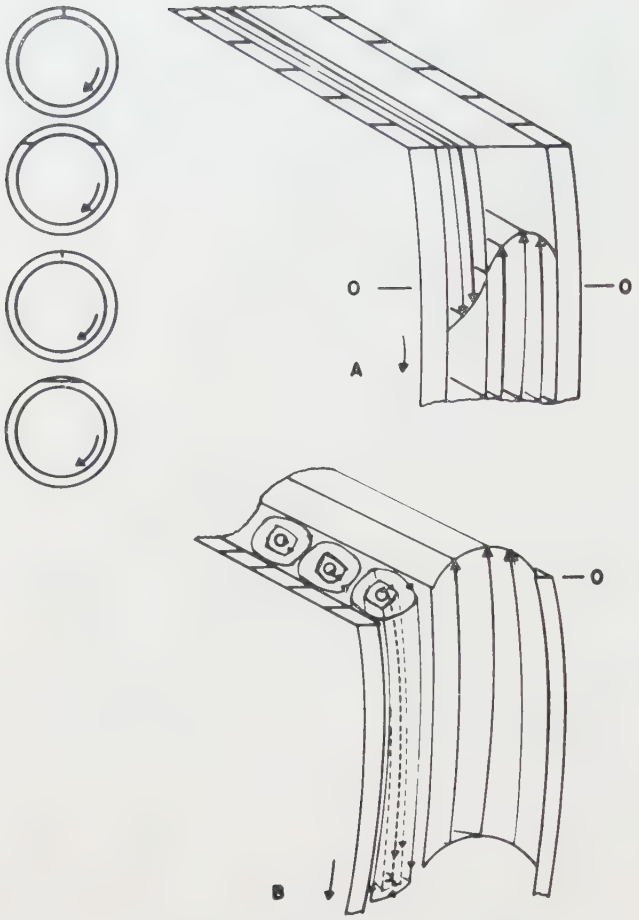

Fig. 9. Fluid motion with reversed flow

Fig. 10 Photograph of fluid motion with reversed flow [after Brewster and Nissan (15)]

partial reversal of flow occurs. A portion of the fluid moves completely around the annulus while a portion makes a "hairpin" turn and reverses direction. Such a condition is similar to the streamline flow shown in Fig. 9A but the condition of a zero velocity streamline at $d/3$ is no longer essential. Brewster and Nissan (*15*) show that the streamline of zero velocity may be approximated by:

$$\frac{d_0}{d} = {}^1/_3\left[1 + \frac{2d'}{d}\right] \qquad (20)$$

It is also stated that of the two potentially unstable regions, the region adjacent to the inner cylinder will become unstable first. By use of the above equation, δ/d may be calculated and the critical angular velocity may again be computed from equations (10) and (10a). The critical laminar motion is similar to that shown in Fig. 9B, but the criterion of $\delta/d = {}^1/_3$ no longer applies.

If the partial barrier is made smaller and extrapolated to a limit of zero it may be observed that this type of flow will approach the simple system described in Fig. 3. Hence a complete circuit of the various fluid motions between concentric cylinders has been described. The parameter P, as defined by equations (10) and (10a), may be applied to all of these systems for the prediction of the onset of unstable flow.

Heat Transfer Between Concentric Rotating Cylinders

A typical example of the influence of these patterns of flow on engineering parameters involved in fluid systems is their effect on heat transfer. Nissan and Haas (*16*) have recalculated a number of heat transfer data using the parameter P to represent the circumferential fluid motion. The following correlation has been found for air contained between concentric cylinders:

$$1 < P/P_c < 3 \quad \frac{Nu}{Nu_{\text{cond.}}} = \left(\frac{P}{P_c}\right)^{0.7}$$

$$3 < P/P_c < 40 \quad \frac{Nu}{Nu_{\text{cond.}}} = 0.5 + \left(\frac{P}{P_c}\right)^{0.5} \qquad (21)$$

The general definition of Nusselt number in an annulus is:

$$Nu = \frac{h(D_2 - D_1)}{k} = \frac{2hd}{k} \qquad (22)$$

Following this definition the Nusselt number for conduction controlling may be defined as:

$$Nu_{\text{cond.}} = \frac{2d/a}{\ln\,[(d/a) + 1]} \qquad (22a)$$

For $d/a \rightarrow 0$ this may be reduced to

$$Nu_{\text{cond.}} = 2.0 \qquad (22b)$$

SUMMARY

The parameter P has been used to represent the circumferential flow pattern for various types of flow between concentric rotating cylinders. A qualitative description of the flow caused by various procedures has been given and the method of quantitatively predicting the point of critical flow has been described.

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Received Oct. 30, 1959. Presented at the 14th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Pittsburgh, Pa., Oct. 12–15 ,1959.

The authors wish to thank the Procter and Gamble Co. for their Fellowship support to F. C. Haas.

Power Transfer Within Wet Felts

M. J. OSBORNE, JAY KNOWLES, and C. C. COLLINS

The widespread use of the vacuum pickup machine made it desirable to measure the power distribution within the felt section on this type machine. A study was made to determine (1) the effect of power transfer on felt life, (2) the practical amount of power to be transmitted through wet felts, and (3) the power requirements for driven rolls within a felt section.

To study this problem on production machines, practical methods were developed to measure and calculate power flow without interrupting machine production. A description of these methods and measuring instruments is given in detail. The methods are explained in general terms so that the same principles of measurement and calculation can be used for any paper machine. The study concludes that (1) using presently accepted drive constants and operating conditions it is unlikely that power flow into felts will have an appreciable effect on felt life, (2) in normal operation the power flow from motors to produce dynamic tension is small compared to static tension in the felts, (3) TAPPI-recommended power constants for driven rolls in felt sections appear to be correct, and (4) additional studies be made to determine optimum static as well as dynamic felt tension.

PURPOSE OF REPORT

The widespread use of the vacuum sheet transfer machine for making kraft and newsprint began in the early 1950's. As the demand for paper production grew, the operating speeds of these machines were pushed higher and higher. These new, wide high-speed machines with common felt sections required new operating techniques as compared with the slower speed open machine. While the goal of increased paper production was successful, operating problems did arise that required investigation. One problem presented was short felt life encountered on some of these machines. The power distribution within a felt section was certainly a factor in the overall felt life problem.

A study of the power distribution within the felt section was started for a number of reasons:

1. The effect of power transfer through the felts on felt life was unknown. Studies had not been made to determine how much power could be transmitted through a certain felt without injury to the felt. Opinion had been advanced that power balance disturbances sometimes noted during transient conditions such as starting and stopping could be responsible for the rapid deterioration and even rupture of some of the wet felts on machines.

2. It was desirable to determine, if possible, the practical amount of power to be transmitted through wet felts.

Having equipment available to put power into a felt can be a valuable asset and should be used to full advantage. Before this power can be used to advantage, however, it is necessary to know where the power is going and how it is being used or else it could do more harm than good.

If the power flow is unknown, then it is similar to driving an automobile without a gasoline gage and without a method of measuring or estimating the distance traveled. Therefore, to use power as an asset we must not only know how much is being used, but also where it is being used. The ideal amount of power transmission by a felt is not known, but it was believed that the power transmitted by a felt should be held as close to the minimum as possible, this minimum being the amount of power necessary to make the felt lie out flat on the machine so it will not wrinkle, pucker, or cut as it enters each succeeding nip. The practical amount of power transfer could be defined then as the minimum power transfer plus that additional amount required, if any, for proper sheet drying, sheet transfer, felt cleaning, and other papermaking problems.

3. The power constants which were being used for various driven rolls in the felt section of a vacuum sheet transfer paper machine needed verification. Since the widespread use of the vacuum sheet transfer machine began after the 1950 TAPPI report on Paper Machine Power Requirements, there were no official power constants available for driven rolls within the felt section on this type machine. TAPPI recognized the importance of accurate constants and at the time this study started, all paper machine power constants were being reviewed by a subcommittee of the Electrical Engineering Committee under TAPPI Project No. 358. Even

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conventional equipment such as main suction presses appeared to consume more power on the high-speed machines than on the slower machines. Two probable factors accounted for this increased power consumption. First, presses were being operated at higher nip pressure and, second, the high-speed suction rolls required the addition of silencer strips. Increased nip pressure resulted in higher power consumption and there was some evidence that silencing strips also consumed considerable power. The power consumed by silencing strips appeared to be a variable dependent on the quantity of shower water used inside the roll for lubrication.

Although the study had begun on newsprint machine, it was expanded to include a modern cylinder board

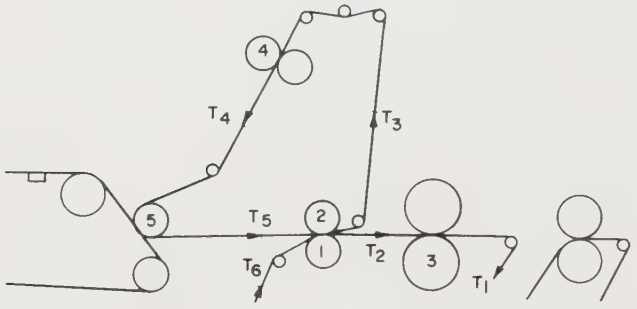


Fig. 1

machine and a high-speed, vacuum-transfer kraft machine. The expansion of this study was made at the request of the Electrical Engineering Committee of TAPPI.

GENERAL PROCEDURES USED

The data for this report were taken from production machines. It was necessary therefore to establish practical assumptions and test procedures that would result in an absolute minimum amount of lost production time and which would give good practical results using instruments and equipment readily available to the average mill.

These procedures and assumptions can best be understood by examining the felt run on a typical vacuum transfer machine (Fig. 1).

Power is flowing into the felt section through dc motors at rolls 1 through 5 (bottom transfer press no. 1, top transfer press no. 2, bottom main press no. 3, wringer no. 4, and pickup no. 5). At each point of power input a portion of the power will be absorbed in the driven roll and the remaining amount will flow into the felt producing tension and stretch.

If we assume the felt tension at T_1 and T_6 are equal and there is no power transfer from the felt section to the wire at the pickup we establish the following relationships:

1. Power input to main press is equal to the power absorbed in the press plus the power transferred to the felt between the main press and the transfer press. As a mathematical equation this would be represented by:

$$PI_3 = PA_3 + (T_2 - T_1)HP$$

where

PI = input horsepower (i.e., PI_3 = input horsepower to main press).

PA = absorbed horsepower.

$(T_2 - T_1)HP$ = horsepower required to change the felt tension from T_1 to T_2.

2. Power input to the pickup is equal to the power absorbed in the pickup plus the power transferred to the felt between the pickup and the wringer. As a mathematical equation this would be expressed by:

$$PI_5 = PA_5 + (T_4 - T_5)HP$$

3. Power input to the wringer is equal to the power absorbed in the wringer plus the power transferred to the felt between the wringer and the transfer press. As a mathematical equation this would be expressed by:

$$PI_4 = PA_4 + (T_3 - T_4)HP$$

4. Power input to the transfer press is equal to the power absorbed in the transfer press plus the power transferred to the pickup felt between the transfer press and pickup plus the power transferred to the transfer felt at T_6. As a mathematical equation this would be expressed by:

$$PI_1 + PI_2 = PA_1 + PA_2 + (T_6 - T_2)HP + (T_5 - T_3)HP$$

Table I. Power Transfer from Felt to Wire

Pickup down			*Pickup raised*			
Couch, amp.	*Wire turning, amp.*	*Total, amp.*	*Couch, amp.*	*Wire turning, amp.*	*Total, amp.*	*Net change, amp.*
320	270	590	360	340	700	+110
140	520	660	120	580	700	+40
200	560	760	210	600	810	+50
60	515	575	60	565	625	+50
180	630	810	185	660	845	+25
190	660	850	240	700	940	+90
200	150	350	200	170	370	+20
180	740	920	200	800	1000	+80
200	680	880	200	660	860	−20
180	750	930	210	760	910	−20
200	680	880	215	660	875	−05
160	540	700	170	640	810	+110
190	660	850	240	700	940	+90
						620

Average = 620/13 = 48 amp.

At 1.5 amp./hp., 48 amp. = 32 hp.
Felt section pulling wire section.

As stated, one assumption made to establish these relationships was that there would be no power transfer to or from the felt section at the pickup nip with the fourdrinier section.

During the period that this power study was being made within the felt sections, another investigation on power transfer around a fourdrinier wire was being made. Concurrently with this power work on the fourdrinier, a series of tests were made of power transfer between the felt section and the wire. Approximately 100 tests were made on 12 high-speed machines of the amount of power transferred from the felt to the wire. It was generally found that power was transferred from the felt to the wire and the magnitude was in the order of 10 hp., but sometimes was as great as 50 hp. On occasions it was found that power was actually being transferred from the wire to the felt, but this was not frequently the case. For all practical purposes during these power studies, the machines under study were adjusted so that there was no power transfer between the felt and the wire. Table I, indicates a few actual readings of power transfer between these sections in

normal operation. There are special reasons beyond the scope of this report for some of the relatively high power transfer shown in Table I.

Many machines will not have exactly the same felt runs or driven rolls as shown in the above illustration. With different felt runs the same power formulas will not apply, but the same principles can be used to establish new formulas to suit any machine or felt run.

Once the power equations had been established it was necessary to find a practical means of measuring each power component.

Power into each driven roll was measured with conventional d.c. voltmeters and ammeters. The power output from each motor was obtained from the product of the motor rating in horsepower times the ratio of load amperes to motor rated amperes times the ratio of machine operating speed to machine rated speed or mathematically:

$$HP_{out} = HP_{motor} \times \frac{\text{load amp.}}{\text{rated amp.}} \times \frac{\text{machine operating speed}}{\text{machine rated speed}}$$

It is recognized that the above formula will not yield absolutely accurate results, but this formula is easy to use and is accurate within practical limits. Machine rated speed is that speed at which rated motor voltage is reached.

Table II. Paper Machine Transfer Felt Test Stretch Versus Tension

Stretch, in.	*Load, lb.*	*Tension, in./1%*
	2 × 100-in. Felt	
0.25	2.00	4.00
0.50	3.75	3.75
0.75	4.75	3.17
1.00	6.25	3.12
1.25	7.75	3.10
1.50	9.25	3.08
1.75	11.50	3.28
2.00	13.50	3.38
2.25	16.25	3.61
2.50	17.25	3.45
	4 × 100-in. Felt	
0.25	2.25	2.25
0.50	4.00	2.00
0.75	4.75	1.59
1.00	6.00	1.50
1.25	8.75	1.75
1.50	10.50	1.75
1.75	13.00	1.86
2.00	17.25	2.16
	6 × 100-in. Felt	
0.25	3.25	2.16
0.50	5.25	1.75
1.00	10.00	1.67
1.50	17.75	1.97
		56.35
Average = 56.35/22 = 2.56 lb./in./1%		

With input power established it was necessary to find a method to determine the power transmitted to the felt. Differential felt tensions would be suitable since, knowing the speed of the felt, differential felt tension could be converted directly to horsepower.

To accurately measure felt tension at various places on the machine would have required full width tensiometer rolls or dynamometers installed on the felt stretch rolls. Since tensions would be required at various points on the machine this method would be complicated, expensive, and interfere with normal production. For these practical reasons it was decided not to use felt tensions as the basis for calculations.

Felt stretch could be satisfactorily measured. For a felt the tension is proportional to stretch since stress is proportional to strain and, therefore, power input to the felt could be calculated from stretch measurements. Felt manufacturers confirmed the relationship between stretch and tension for pickup and transfer felts on kraft and newsprint machines and stated that about $2^1/_2$ lb. per in. tension would result in a 1% stretch in the felt.

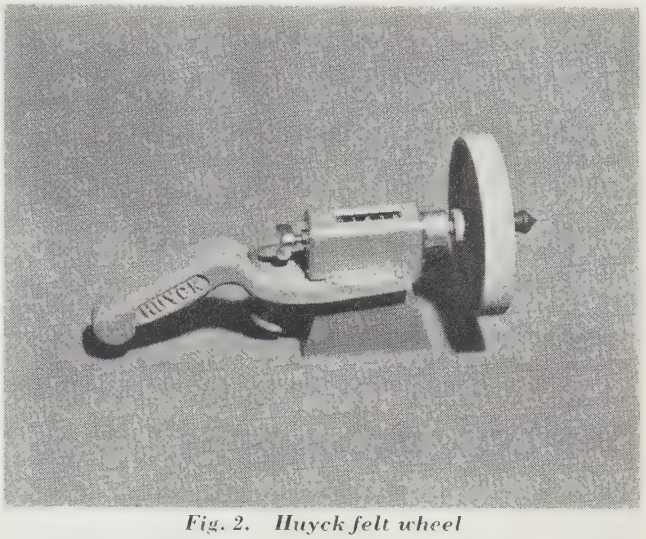


Fig. 2. Huyck felt wheel

To further establish the relationship between stretch and tension tests were made using a discarded transfer felt. Three strips of felt 100 in. long and 2, 4 and 6 in. wide were hung from spring scales and the strips were stretched. Although the felt was dry and worn, the data obtained confirmed the conversion figure of $2^1/_2$ lb. per in. tension per 1% stretch. Complete data taken on felt stretch is given in Table II.

The power input to a felt at a given point can be calculated from this data as follows:

$$HP_{\text{in felt}} = \frac{(L_2 - L_1)}{L_1} \times 100 \times 2^1/_2 \text{ lb./\% stretch} \times \frac{W \times S}{33{,}000}$$

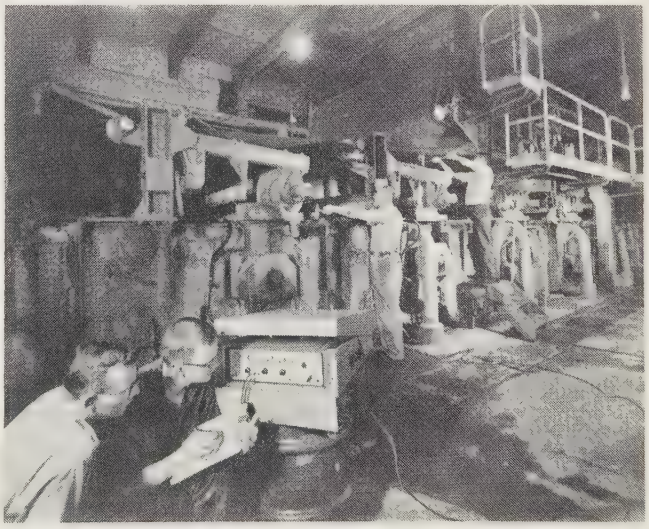


Fig. 3. Operating electronic speed tester

where

L_1 = felt length ahead of the driven roll.
L_2 = felt length behind the driven roll.
W = machine width, in.
S = machine speed, f.p.m.

The measurement of felt length was made with the Huyck felt wheel. The felt wheel (Fig. 2) is a wheel 1 ft. in circumference directly coupled to a digital revolution counter. If the wheel is placed on the felt and a count started exactly as the felt mark goes by and stopped as the mark comes around the second time then the digital reading will be the equivalent felt length at the point being measured. For higher accuracy, rather than measure only one complete felt pass, it is the usual practice to measure 10 or more complete passes of the felt and divide the total reading obtained by the number of felt passes made. The felt wheel provides a method of obtaining felt stretch, for if measurements are made at two places where the felt length is different then the difference in felt length obtained will be the felt stretch in feet. This tool is sufficiently accurate to obtain repetitive measurements on a given machine and is adequate for basic power calculations.

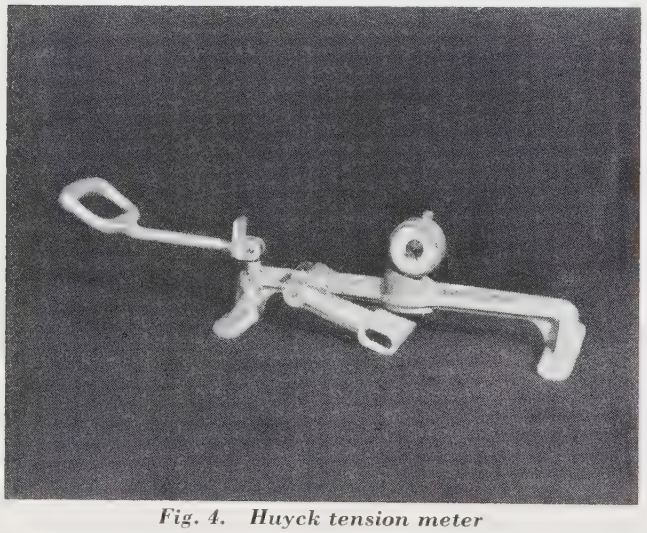


Fig. 4. Huyck tension meter

If even greater accuracies of felt stretch is desired then the electronic tester (Fig. 3) can be used. This instrument is used to accurately measure the felt speed at various points around the loop. The felt length and speed must be established at a selected base point. Once the base speed and length have been established, measurements of felt speed around the loop can be made. The felt length at each selected point can be determined by multiplying the base felt length by the ratio of measured felt speed to the base felt speed. The added calculation involved in this method makes it second choice compared to the method using the felt wheel.

As noted, to determine power transfer in a felt it is necessary to convert stretch to tension. This emphasizes the fact that a simple portable instrument to measure dynamic felt tension is highly desirable. Even if the stretch principle is used for measurement the stress-strain relationship must be established through laboratory tests or by direct reading tension instruments.

Some direct readings of felt tension can be made with the Huyck Felt Co. Huyck-Meter. This instrument is limited in its use to measurements made on felt runs that approximate horizontal planes.

Since most felt runs have various tension points that occur on other than horizontal planes, this instrument, by itself, cannot be used to obtain the data presented here. The felt tension meter is still a useful tool, however, for there are usually enough horizontal planes in the felt run to make measurements of both tension and length to establish the relationship between stretch and tension.

The tension meter (Fig. 4) has a weight pivoted between two fixed supports. To measure felt tension both supports are placed on the felt in as near a horizontal

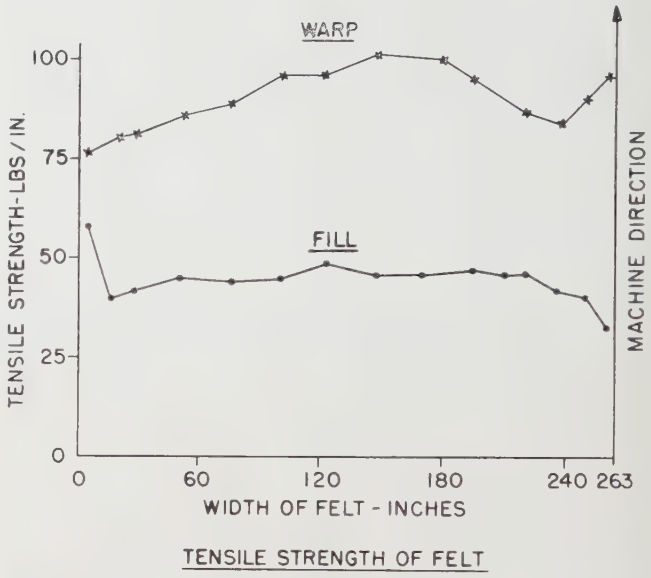


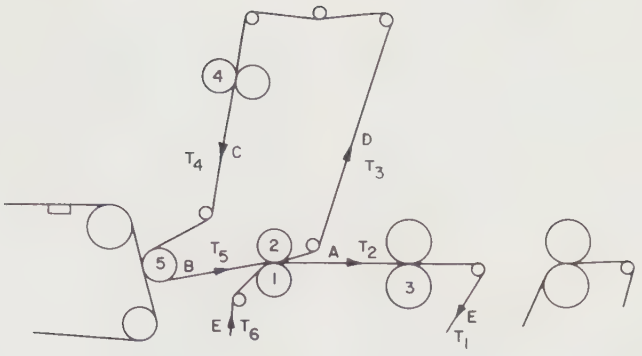
Fig. 5. Test made on worn felts taken from newsprint machine transfer press position. Test made at F. C. Huyck & Sons, Inc., Rensselaer, N. Y.

plane as possible. The weight is then allowed to sink into the felt. A lever arrangement on the weight presses a dial indicator which is inversely calibrated in pounds per inch of felt tension. The farther the weight sinks into the felt, the smaller the tension. The equipment is designed to measure tension while the machine is running.

SUMMARY AND EXPLANATION OF FINDINGS

On similar high-speed machines studied the power transferred to the felts at all points varied from a minimum of zero to a maximum of 36 hp. In terms of tension 36 hp represented 2.1 lb. per in. width. This same felt had a static tension of 6.5 lb. per in. width or a total maximum tension of 8.6 lb. per in. width. On another machine there was no tension differential around the pickup felt loop; however, the static tension in that felt was 19 lb. per in. width. Whether or not the observed maximum tension was enough to damage the felt was unknown since the tensile strength of the felts were not known. To determine the felt tensile strength, F. C. Huyck & Sons, Inc., made tests on a discarded transfer felt (see Fig. 5). The minimum warp tensile strength on this felt was 80 lb. per in. width in the machine direction. On a machine 254 in. wide operating at 220 f.p.m. it would require a 1350 hp. differential to produce 80 lb. per in. tension.

Since both the static and the combined static and



MACHINES A AND B

Power Data

Driven roll	Power input, hp./in. Machine A	Power input, hp./in. Machine B	Power absorbed, W/100 f.p.m. Machine A	Power absorbed, W/100 f.p.m. Machine B	Meas. at point	Power transmitted to felts Hp./in., W/100 f.p.m. Machine A	Power transmitted to felts Hp./in., W/100 f.p.m. Machine B	Tension, lb./in. Machine A	Tension, lb./in. Machine B
Transfer press	0.02	0.017	0.025	0.024	B	0	0	0	0
					E	−0.005	−0.007	−1.6	−2.23
Pickup	0.01	0.009	0.01	0.012	C	0	−0.003	0	−0.95
Wringer	0.009	0.008	0.009	0.005	D	0	0.003	0	0.95
Main press	0.024	0.036	0.019	0.029	A	0.005	0.007	1.6	2.23

Power Formulas

$PI_3 = PA_3 + (T_2 - T_1)\,HP$
$PI_5 = PA_5 + (T_4 - T_5)\,HP$
$PI_4 = PA_4 + (T_3 - T_4)\,HP$
$PI_1 + PI_2 = PA_1 + PA_2 + (T_6 - T_2)\,HP + (T_5 - T_3)\,HP$

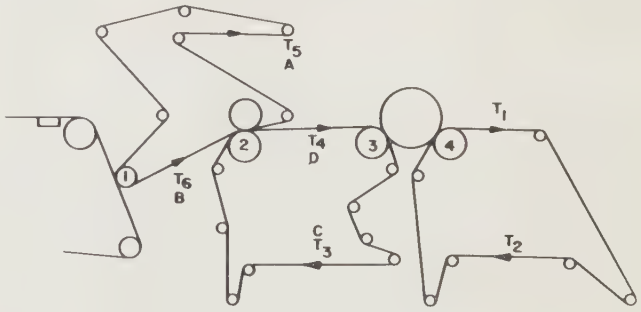
Fig. 6. Machines A and B

dynamic tension measurements made were well under the tensile strength of the felts, it is unlikely that reasonable amounts of power transfer within the felt section would contribute to reduced felt life. With the relatively small amount of data taken it is impossible to state with accuracy what amount of power can be transmitted through the felt continuously without damage (Figs. 6 to 8).

In all instances the dynamic felt tension produced by the drive motors was small compared to static tension put in the felt. Because the machines were in production it was not possible to experiment with different values of static tension and variations in dynamic tension produced no noticeable change in machine operation. For example, two identical machines, in the same mill making newsprint at approximately the same speed had felt tension differences that varied from 15 to 33%. On both of these machines failures of felt guide rolls had occurred that led to the conclusion that the operating felt tensions were excessive and greater than had been expected by the machine designer. The overall operating benefits that may be obtained by reducing static felt tension and using helper motor power to provide felt tension where needed will need to be studied in more detail.

The tension and stretch data given in this report are representative of average readings taken across the face of the machine. Crowning, dubbing, misalignment, and other mechanical factors can result in a certain amount of felt tension variation across the machine. Unless a rigorous investigation is being made of tensions and tension variation, average tension and stretch readings should be sufficient for investigations of this type.

The power required to drive the various rolls within the felt section varied depending on operating conditions. Since only a small number of machines were studied it is impossible to reach firm conclusions on exact power requirements. Even with a small number of machines tested it is possible to examine input power and, using practical judgment, arrive at reasonable operating ground rules. For example while the power absorbed in the wringer roll varied from a power constant of 0.005 to 0.01 the input power to this roll was about 0.01 hp. per in. width per 100 f.p.m. Any difference between the helper power supplied to the wringer and



MACHINE C

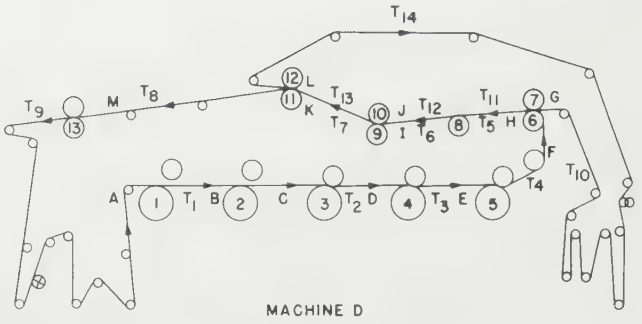
Power Data

Driven roll	Power input, hp./in.	Power absorbed, W/100 f.p.m.	Power transmitted to felts Meas. at point	Power transmitted to felts Hp./in., W/100 f.p.m.	Δ tension, lb./in.
Pickup	0.0046	0.0072	A	−0.0026	−0.943
Transfer press	0.0046	0.0055	B	0.0026	+0.943
			C	−0.004	−1.25
Dual press	0.041	0.037	D	0.004	1.25

Power Formulas

$PI_1 = (T_5 - T_6)\,HP + PA_1$ (suction pickup)
$PI_2 = (T_6 - T_5)\,HP + (T_3 - T_4)\,HP + PA_2$ (transfer press)
$PI_3 + PI_4 = (T_4 - T_3)\,HP + (T_2 - T_1)\,HP + PA_3 + PA_4$ (dual press)

Fig. 7. Machine C



MACHINE D

Power data

Driven roll	*Power input, hp./in.*	*Power absorbed, W/1000 f.p.m.*	*Power transmitted to felts* — *Meas. at point*	*hp./in. W/100 f.p.m.*	*Δ tension lb./in.*
No. 1 mold	0.0009	0.0009	A	0	0
No. 2 mold	0.001	0.001	B	0	0
No. 3 mold	0.0014	0.0005	C	0.0009	0.27
No. 4 mold	0.0018	0.004	D	−0.0022	−0.67
Suction drum	0.0067	0.0061	F	−0.0026	−0.94
1st primary press	0.0023	0.0023	G	0.0032	1.07
			H	0	0
2nd primary press	0.0033	0.0053	I	0	0
Suction primary press	0.0089	0.0008	J	0.002	−0.67
			K	0.01	3.35
			L	−0.002	−0.67
Main press	0.056	0.057	M	−0.001	−0.33

Power Formulas

Cylinder molds:

$$PI_1 = PA_1$$
$$PI_2 = PA_2$$
$$PI_3 = PA_3 + (T_1 - T_2)\,HP$$
$$PI_4 = PA_4 + (T_2 - T_3)\,HP$$
$$PI_5 = PA_5 + (T_3 - T_4)\,HP$$

Suction drum:

$$PI_6 + PI_7 = PA_6 + PA_7 + (T_4 - T_5)HP + (T_{10} - T_{11})HP$$

Primary presses:

$$PI_8 = PA_8$$
$$PI_9 + PI_{10} = PA_9 + PA_{10} + (T_6 - T_7)HP + (T_{12} - T_{13})HP$$
$$PI_{11} + PI_{12} = PA_{11} + PA_{12} + (T_7 - T_8)HP + (T_{13} - T_{14})HP$$

Main press:

$$PI_{13} = PA_{13} + (T_8 - T_9)HP$$

Fig. 8. Machine D

the actual power required will result in power being provided to or taken from the felt. Considering that machine operation, felt runs, felt tensions, etc., can vary considerably between machines and mills; the TAPPI recommended wringer roll drive constant of 0.015 hp. per in. width per 100 f.p.m. provides a reasonable margin for mill operating conditions. It is interesting to note that on one of the machines under study the wringer roll power absorbed was about half that of a wringer roll on a duplicate machine in the same mill. Investigation revealed the suction holes in the roll with the smaller power requirement to be plugged.

Table III

Driven roll	*Recommended drive constant, hp./in. width/100 f.p.m.*
Suction pickup	0.01
Suction wringer	0.015
Suction transfer press	0.03
Suction main press	0.03

While this study was being made there were no official power constants available for rolls within the felt section except for the main presses. The constants in Table III were in general use.

These constants in general seem to be adequate; however, the main presses tend to operate closer to the recommended drive constant than do other driven rolls. For this reason in selecting a drive for main presses it is recommended that the constant of 0.03 hp. per in. width per 100 f.p.m. be considered the minimum. One of the main presses investigated required input power corresponding to 0.036 hp. per in. width per 100 f.p.m. A check on operating conditions revealed the roll was operating with insufficient shower water. An increase in the flow of shower water brought the load down below a constant of 0.03 hp. per in. width per 100 f.p.m.

The effect of silencer strips on power requirements could not be examined under operating conditions. Previous records on two machines being studied taken before the addition of silencer strips indicated the load to be increased an appreciable amount as the silencer strips were added. The amount of load increase depends to such an extent on mechanical conditions that definite power figures are not available.

CONCLUSIONS

1. Under present operating conditions using drive constants recommended it is unlikely that power transfer into the felts will have any appreciable effect on felt life. On all machines studied the differential felt stretch measurements were very small. Even under transient conditions it would appear that reasonable amounts of power transfer from properly adjusted drive motors would not materially effect the life of the felts.

2. The power flow from drive motors into the felts to produce dynamic tension was very small compared to the static tension placed in the felts. The power input at any driven roll ahead of the main presses could be changed by large amounts without any noticeable change in papermaking operation. It is believed that felt static tension could be appreciably reduced in most instances with control of felt tensions around the loop being obtained by drive motor loading.

Until more complete investigations are made it would seem good practice to limit the combined static and dynamic felt tension to that necessary to make the felt lay out flat on the machine so it will not wrinkle, pucker, or cut as it enters each succeeding nip.

3. The recommended power constants in general use for felt section motors appeared to be adequate. These recommended drive constants (RDC) are expressed in hp. per in. width per 100 f.p.m. as follows: main press, 0.03; transfer press, 0.03; wringer roll, 0.015; pickup roll, 0.01. Power absorbed at the main press varies from machine to machine enough so that connected drive should never be sized below that corresponding to a drive constant of 0.03. Further details on recommended power constants are given in TAPPI Data Sheet 145G.

4. It is recommended that more study be given to static as well as dynamic felt tensions. It may be possible to provide better felt cleaning, sheet transfer, and longer felt life if different operating conditions are observed.

5. Power studies similar to this made in individual mills should prove valuable in maintaining constant operating conditions. An occasional check after a complete study has been made would suffice to judge whether or not operating conditions have changed during times when trouble of one sort or another is encountered. As noted on two machines studied, it is possible using the power study method to spot and correct machine mechanical defects as they occur rather than let the defects become serious enough to cause expensive unscheduled machine down time.

Received Oct. 30, 1959. Presented at the 14th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Pittsburgh, Pa., Oct. 12–15, 1959.

Alkaline Pulping of Poplar and Birch

The Influence of Sulfidity and Effective Alkali on the Rate of Pulping and Pulp Properties

G. W. LEGG and J. S. HART

Although fundamental data on hardwood pulping have become of paramount importance in guiding the industry as it utilizes increasing quantities of these woods, yet of all the information available in the literature on the alkaline process, there has been very little on the pulping of hardwoods. This report, which is part of an over-all program of study of the alkaline process being carried out at this Institute, covers an investigation of the influence of various cooking variables, within the practical limits found in mill practice, on the kraft pulping of two hardwoods: poplar (*populus tremuloides*), and birch (*betula papyrifera*). The investigation confirms the findings of previous studies on western red cedar (*9*), which indicated that the pulping rate increases with increasing sulfide and effective alkali charge. It expands this information further by establishing an upper limit of sulfide charge beyond which no increase in pulping rate or pulp quality are manifest. The maximum rate remains the same regardless of the amount of effective alkali used, while the sulfide contributes less to increasing the rate as the effective alkali charge is increased. The work also shows that high alkalinity of the liquor, low sulfide charge, and lower cooking temperature have an adverse effect on the pulp quality. The pulping rates of poplar and birch were very similar. It is, in fact, shown that, regardless of variation either within the same wood species or between the two hardwood species, wood constituents are removed during cooking in constant proportion to the amounts present in the original wood. Furthermore, the studies indicate that variations *within* the species account for greater differences in pulp quality and pulping properties than any other processing variable which was studied.

Increasing difficulties in the procurement of softwoods have caused increasing interest in the utilization of hardwoods. So far, the amount of information available on hardwood pulping remains comparatively small, and much of this has been obtained in experiments not designed with practical conditions in view.

Softwoods have received by far the greater share of attention in studies of the alkaline process. They were, for instance, chiefly used by a number of authors (*1–4*) to study the effect of alkali concentration in alkaline cooking. In general, these authors all concluded that pulp strengths, viscosity, and yield were reduced by increasing the alkali concentration above a certain level. This upper limit was suggested to be 15 g.p.l. as effective alkali concentration, above which pulp strengths decreased while the pulping rate was not increased significantly.

Hagglund (*5*) and Hart and Strapp (*6*), studying the affects of sulfidity on the pulping of spruce, found that an increase in the sulfidity of the cooking liquor improved its ability to remove lignin. Others, (*7, 8*) however, suggested later that this increase had a probable upper limit beyond which no further improvement in pulp quality would be obtained. This was confirmed in a more recent paper by Christiansen, Hart, and Ross (*9*). Evaluating the role of sulfide charge in the pulping of western red cedar, they combined their own data with that from Hagglund's (*5*) work, and deduced this optimum quantity to be of the order of 5%. Below 5%, strength and yield were reduced; above it, improvements in pulp quality were not significant. These findings, however, all related to softwoods and there was nothing to indicate that hardwoods would behave similarly under the same conditions. Information on hardwoods was scattered and scarce.

More specific to hardwoods was a comparison by two authors (*10, 11*) of hard- and softwood kraft pulps. In this it was suggested that poplar pulped more easily than spruce because the lignin in poplar had a lower degree of condensation. It was also found that the poplar required a lower cooking temperature, and that the hard- and softwood pulp strengths were similar, except that poplar had less resistance to tear.

Although the chemical requirements for pulping hardwoods were generally agreed to be less than those for softwoods, beyond this there was very little unanimity. Brauns and Grimes (*13*) had suggested that for the pulping of spruce, 16% NaOH was required, of which 25% was used in delignification and the remainder for neutralizing degradation products of the carbohydrates. In the pulping of hardwoods, two authors agreed that the chemical requirements were less, but while one (*10*) suggested these to be from 1 to 2% sulfur, another (*12*) recommended 1.35% sodium sulfide and 11.6% sodium hydroxide.

In a comparison of hardwood species, Bruun (*14*) showed that under the same kraft cooking conditions, using 14% active alkali at 21% sulfidity, aspen pulped

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faster, to a lower lignin content and higher total yield, than birch or black alder. Earlier, Jayme (*15*) had standardized the conditions of the kraft process and had used it to classify various poplar samples in terms of their "cellulose" contents. He was able, at the same time, to correlate variations in yield with variations in the carbohydrate contents of the original woods, and found this correlation to hold both within the same, and between different hardwood species. This correlation, between pulping properties and variability of wood composition, both within and between species, has received further attention. Klauditz (*16*) found the major deviations from a mean cellulose content of 42.5%, for both birch and poplar, to be due chiefly to biological-mechanical factors, and to be relatable to the presence of tension wood. Increases of up to 6% in sulfate pulp yields were attributed by Jayme and co-workers (*17*), in a series of articles, to age, rate of growth, locality, density of stand, and environment of the trees during growth.

Certainly the nature and relatively high content of total carbohydrate of hardwoods indicate their excellent potential as a source of papermaking raw material. But an understanding of the fundamental variables associated with hardwood pulping is required before substantial improvements in yield, quality, and efficiency of mills currently using or anticipating the use of these woods can be expected.

The present studies, and those reported earlier, (*9, 23*) are part of a program of study of alkaline pulping being conducted by this Institute. The overall plan of this work is to determine the influence of all variables within the alkaline process and ultimately, it is hoped, to derive single physico-chemical functions to factorially control this process. The present paper, however, is devoted to a pulping study of two hardwoods: birch and poplar.

Table I. Location and Description of Hardwood Samples

Lot no.	1	2	3	4	5	6	7
Species	Poplar	Poplar	Poplar	Poplar	Poplar	Poplar	Birch
Source	K.V.P.	Dryden	Howard Smith	Abitibi	C.I.P.	C.I.P.	C.I.P.
Area	Ramsay, Ont.	Wabigoon Lake, Ont.	Granby, Que.	Pine Falls, Man.	Noranda, Que.	Harrington, Ont.	
Elevation, ft.	1400	1210	1000	900	1000	6–700	
Soil	Sandy loam (dry)	Sandy loam (stony)	Black and gravel	Clay underlaid granite	Clay	Light–sandy	
Precipitation	35	23	...	16–20	23	32	
Stand:							
Average age	65	40	25–30	65	60	120	
Species	Poplar and jackpine	Poplar and jackpine	M/H	Spruce, Balsam, Poplar	Spruce, Birch, Poplar	M/W	
Cords/acre	16	15	12	25	6	25	
Sample:							
No. of trees	2	6	2	2	2	2	1
Age, yr.	48	23	37	50	20	30	50
Rings/in.	13	8	8	13	8	...	12
Density, g./cc.	0.356	0.368	0.406	0.393	0.390	0.36	0.530

OBJECTIVE

To investigate the influence of various cooking variables, within the practical limits found in mill practice, on the kraft pulping of poplar and birch.

PLAN

The experimental work covered by this report was carried out in two parts. The first part, carried out in stainless steel bombs, embodied a study of the influence of pulping variables on the pulping rate of poplar (*Populus tremuloides*). Some of this work was then repeated using birch (*Betula papyrifera*). The second part of the work, carried out in the Institute's 2-cu. ft. digesters, used the data so obtained to study the influence of the kraft pulping variables on various paper qualities. Variability of pulping properties, both between hardwood species and within the same species from different areas, was also studied.

Table II. Chemical Analysis of Hardwood Samples

Species	*Poplar*						*Birch*
Lot. no.	1	2	3	4	5	6	7
Lignin, %	17.9	17.8	17.2	17.2	16.8	18.8	19.1
Pentosan, %	20.5	20.0	19.8	20.2	20.2	20.3	25.5
Holocellulose, %	73.1	71.3	72.7	74.4	73.4	73.6	79.2
Alpha-cellulose, %	47.9	46.6	49.9	47.3	48.0	47.5	47.7
Ash, %	0.47	0.35	0.41	0.35	0.34	0.35	0.20
Sol. in:							
1% NaOH, %	19.4	19.4	17.5	18.5	18.2	21.0	17.1
Cold water, %	1.5	1.4	1.0	1.2	1.2	2.0	1.5
Hot water, %	2.9	2.9	2.4	2.9	2.6	3.8	1.8
Alcohol benzene, %	2.8	3.0	2.3	2.6	2.7	3.5	3.0
Ether, %	1.3	1.4	1.0	1.4	1.5	1.2	2.0

EXPERIMENTAL PROCEDURE AND RESULTS

Wood

The hardwoods used in this work were obtained se-

lectively from various growing areas in Canada, e.g., Montreal, Great Lakes, Western Ontario, Northern Quebec, and Manitoba. A detailed description of the locations and growing conditions is given in Table I, and the chemical and physical properties of the various samples are given in Table II.

Table III. Effect of Sulfide Charge at 12% Effective Alkali Charge

Poplar—Lot 6—Bomb Cooks

Cook no.	Time at 170°C., min.	Yield, %	Roe no.	Lignin, %	Pentosan, %
		0% Sulfide Charge			
M 697	0	76.7	20.2	16.6	
M 698	10	72.7	18.1	14.8	..
M 699	20	70.3	16.8	13.5	...
M 700	30	69.7	15.5	12.5	...
M 701	45	67.1	13.8	10.9	...
M 702	60	64.4	11.5	9.2	..
M 703	75	63.8	11.4	9.2	.
M 704	90	61.9	9.5	7.8	
		1% Sulfide Charge			
M 713	0	74.2	18.9	14.8	
M 714	10	69.6	16.2	12.8	
M 715	20	66.7	14.1	11.0	
M 716	30	65.2	11.8	9.9	..
M 717	45	63.4	10.5	8.2	..
M 718	60	61.2	7.7	6.6	..
M 719	75	60.0	6.8	5.7	...
M 720	90	59.7	6.3	4.8	.
		2% Sulfide Charge			
M 814	0	70.3	17.1	14.4	17.1
M 815	20	65.7	11.1	9.4	17.3
M 816	30	62.3	8.9	7.4	17.6
M 817	45	60.3	6.7	6.3	18.2
M 818	60	58.7	5.8	5.0	18.4
M 819	90	57.4	3.6	3.3	18.7
		3.2% Sulfide Charge			
M 661	0	71.0	14.5	12.9	
M 662	10	66.2	9.9	9.1	..
M 663	20	63.3	6.6	6.3	
M 664	30	61.7	4.6	4.5	.
M 665	45	58.7	3.0	3.2	..
M 666	60	58.6	1.7	2.3	.
M 667	75	58.4	1.0	1.9	.
M 668	90	58.1	1.0	1.7	
		4.5% Sulfide Charge			
M 797	0	70.9	14.8	12.0	17.0
M 798	10	64.8	10.0	8.3	17.3
M 799	20	62.1	6.6	5.7	17.2
M 800	30	61.2	5.1	4.4	17.2
M 801	45	59.9	3.8	3.1	17.7
M 802	60	58.3	2.8	2.3	17.9
M 803	75	58.1	2.2	2.0	17.3
M 804	90	57.5	2.3	2.1	17.7
		10% Sulfide Charge			
M 845	0	67.3	12.0	10.1	17.8
M 846	20	59.3	4.1	3.5	18.5
M 847	30	58.1	2.9	2.8	19.0
M 848	45	56.9	2.1	1.8	18.5
M 849	60	56.2	1.6	1.5	18.5
M 850	90	55.1	1.6	1.6	18.8

Constants: Rise-to-temperature—1°C./min.;
Maximum temperature, 170°C.;
Liquor-to-wood ratio—4.5:1 (including chip moisture).

Chips were prepared from the individual samples of wood using a commercial chipper at the mill of Howard Smith Paper Mills Limited, Cornwall, Ont. Upon arrival at the Institute, the chips were screened on a vibrating chip screen to remove fines and oversized chips, and then, to prevent decay, were spread out to dry at room temperature to about 12% moisture. The dried chips were then thoroughly mixed and stored in fiber drums at just above 0°C. (32°F.) in the Institute cold room. After moisture determinations had been made, 100-g samples (O.D. basis) were prepared from the stored chips for the bomb-scale cooks. These chip charges were sealed in polyethylene bags and stored in a freezer at −23°C. (−10°F.).

Liquor

The cooking liquors were prepared from concentrated and decanted solutions of technical grade sodium hydroxide and sodium sulfide. Water was used as a diluent.

COOKING

Bomb Cooks. The stainless steel bombs used in this part of the study have been described in the paper by Kerr and Harding (*18*).

The chip charges, after removal from the freezer, were allowed to thaw out at room temperature before being charged to the bombs. The cooking liquor, at room temperature, was then added to the bombs to give a liquor-to-wood ratio of 4.5:1, including chip moisture. The bombs were sealed and placed in a glycol bath controlled at 80°C. in which the bombs were rotated at 4 r.p.m. Temperature equilibrium was reached within 2 min. after which it was raised to 170°C. in 90 min., being maintained at this temperature for the prescribed time. At the end of the cook the bombs were cooled rapidly in a bath of quenching oil.

Table IV. Effect of Sulfide Charge at 16% Effective Alkali Charge

Poplar—lot 6—bomb cooks

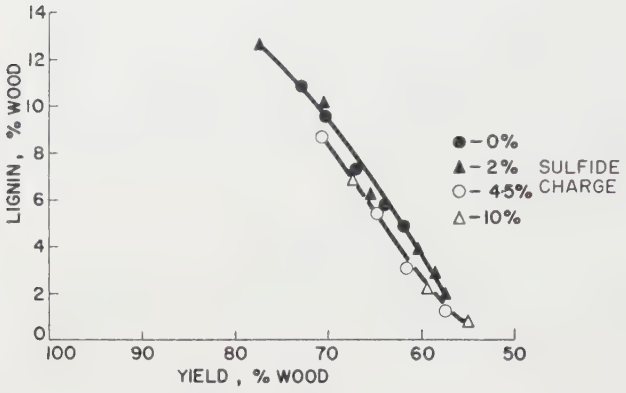
Cook no.	Time at 170°C., min.	Yield, %	Roe no.	Lignin, %	Pentosan, %
		1% Sulfide Charge			
M-2 916	0	72.1	19.3	16.1	14.2
M-2 917	20	65.8	12.5	10.5	15.3
M-2 918	45	59.8	6.8	5.7	16.5
M-2 919	90	56.2	2.8	2.7	17.4
		2% Sulfide Charge			
M-2 920	0	69.3	16.6	13.4	14.6
M-2 921	20	60.3	7.4	6.3	15.3
M-2 922	45	56.0	3.0	2.6	16.9
M-2 923	90	55.0	2.0	1.9	17.5
		3% Sulfide Charge			
M-2 931	0	69.2	16.2	13.1	15.2
M-2 932	20	59.2	6.7	5.5	16.2
M-2 933	45	55.8	2.6	2.4	17.3
M-2 934	90	54.0	1.5	1.5	17.9

Constants: Rise-to-temperature—1°C./min.;
Maximum temperature, 170°C.;
Liquor-to-wood ratio—4.5:1 (including chip moisture).

The pulp obtained from each bomb was defibered in the British disintegrator, or, in the case of high yield pulps, in the Waring Blendor. They were then washed with distilled water, and finally, were dried in the oven for yield determination. After soaking and redispersion, sheets were prepared from the pulps upon which chemical tests were made according to the CPPA and TAPPI Standard methods.

Two-Cu. Ft. Cooks. The equipment used for the 2-cu. ft. cooks has been described in a paper by Potter (*19*).

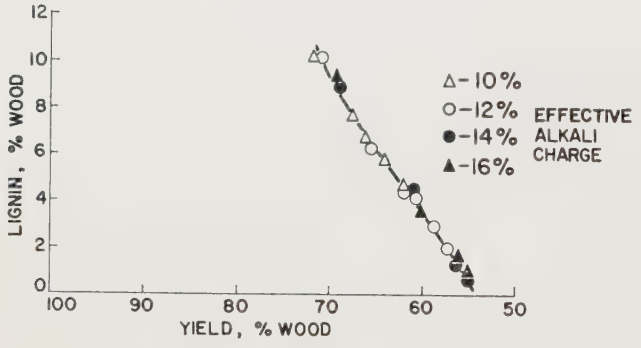
The digester charges, equivalent to 6.5 kg. (O.D. basis), were prepared from the chips which had been kept in cold storage and were charged to the digester in a stainless steel basket. After the digester had been capped, the contents were subjected to steaming for 20



Bomb cooks—poplar lot 6. Effective alkali charge, 12%; cooking temp., 170°C.

Fig. 1. Lignin versus yield

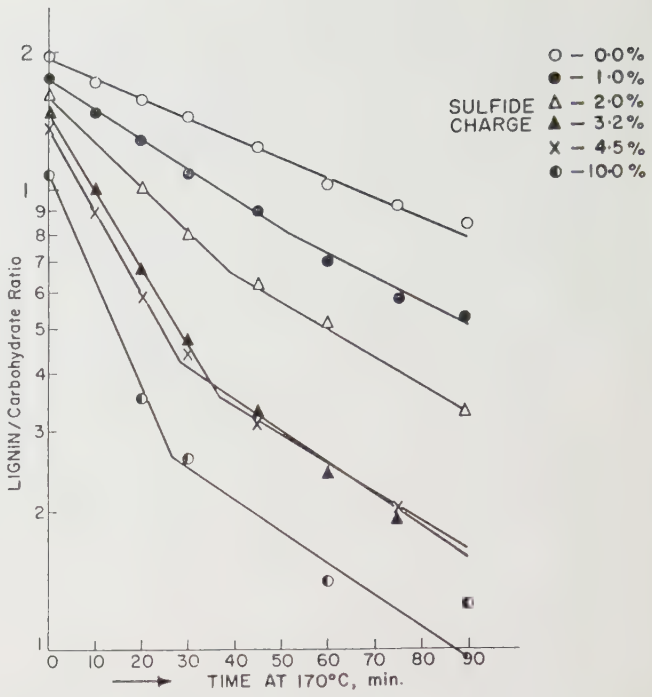
min. and to two purges, each of 2 min. at 20 lb. The cooking liquor was charged to the digester at 80°C. to give a liquor-to-wood ratio of 4:1, excluding chip moisture. After completion of the liquor charging, indirect heating was applied to the digester to give a temperature rise of 2°C. per min. to a maximum temperature of 170°C., except where otherwise stated. Upon completion of the cook, the liquor was blown from the digester system, the lid taken off and basket and contents removed.



Bomb cooks—poplar lot 6. Sulfide charge, 2%; cooking temp., 170°C.

Fig. 2 Lignin versus yield

The digested chips were washed over a 150 mesh, stainless steel wire in a screen box and were then disintegrated in the Cowles Dissolver at yields less than 65%, or in the laboratory 12-in. Sprout-Waldron refiner at yields higher than 65%. Only those pulps not requiring refining treatment were screened on a 13 cut Sprout-Waldron flat-screen. The yield of pulp was determined by dilution and consistency measurement. Physical properties of the pulps were determined by the standard procedure using a Valley beater and the chemical properties were determined on airdried handsheets according to the CPPA and TAPPI Standard methods.



Bomb cooks—poplar lot 6. Effective alkali charge, 12%; temp. rise, 1°C./min.; cooking temp., 170°C.

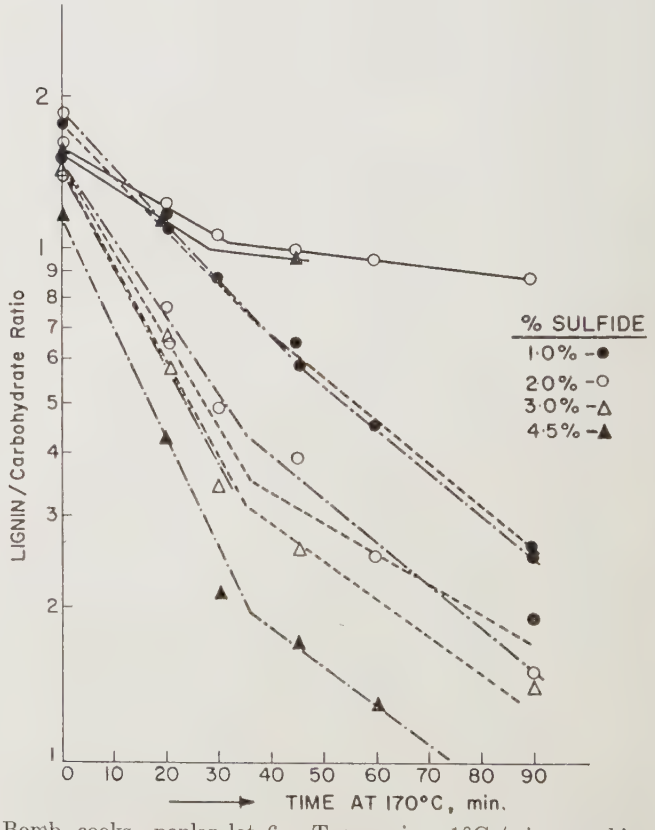
Fig. 3. Effect of sulfide charge on lignin/carbohydrate ratio

Viscosities were determined upon the pulps after bleaching by the Yorston procedure (*20*).

DISCUSSION OF RESULTS

Bomb Cooks

The effect of sulfide charge upon lignin removal in



Bomb cooks—poplar lot 6. Temp. rise, 1°C./min.; cooking temp., 170°C.; effective alkali charge—10% ——, 14% — · —, 16% – – – –

Fig. 4. Effect of effective alkali charge on lignin/carbohydrate ratio

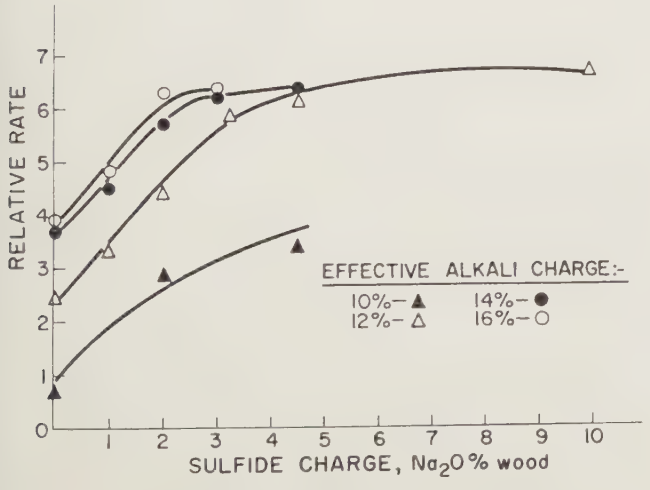
Table V. Effect of Sulfide Charge at 14% Effective Alkali Charge

Poplar—lot 6—bomb cooks

Cook no.	Time at 170°C., min.	Yield, %	Roe no.	Lignin, %	Pentosan, %
		1% Sulfide Charge			
M 888	0	68.7	18.0	15.4	17.0
M 889	20	62.9	12.0	10.5	17.3
M 890	30	61.7	9.2	8.6	17.7
M 891	45	60.0	7.1	6.5	17.2
M 892	60	57.5	4.9	4.6	18.4
M 893	90	55.8	2.7	2.8	19.4
		2% Sulfide Charge			
M 851	0	68.7	15.8	13.0	16.9
M 852	20	60.4	9.0	7.1	17.9
M 853	30	58.7	6.0	4.8	18.0
M 854	45	58.1	4.4	3.9	18.7
M 855	60	56.9	2.8	2.6	19.0
M 856	90	55.5	1.5	1.7	19.3
		3.0% Sulfide Charge			
M 910	0	66.5	15.5	13.0	17.5
M 911	20	60.7	7.6	6.6	18.3
M 912	45	56.8	3.7	3.7	19.0
		4.5% Sulfide Charge			
M 882	0	65.0	12.9	10.4	16.7
M 883	20	58.1	4.8	4.1	18.0
M 884	30	56.0	2.6	2.1	18.0
M 885	45	55.5	2.0	1.7	18.6
M 886	60	55.3	1.5	1.3	18.6
M 887	90	54.5	1.3	1.1	18.7

Constants: Rise-to-temperature—1°C./min.; maximum temperature, 170°C.; liquor-to-wood ratio—4.5:1 (including chip moisture).

relation to total yield is shown in Tables III, IV, V, and VI, and in Fig. 1. These show, between 55 and 80% yield, an almost linear relationship between lignin content of the pulp and yield. They also indicate the change in lignin-carbohydrate ratio during cooking, and show the effect which further variation of the initial liquor composition will have upon this change: at a constant effective alkali charge, i.e., 12%, an increase in the sulfide charge from 0 to 4.5% will cause improved carbohydrate yield at the same lignin content, but that no further improvement is evident when the sulfide charge is increased beyond 4.5%. This is equivalent, at the liquor-wood ratios used in this work, to a sulfidity of 30%: below 2% sulfide charge, or 15% sulfidity, improvements are negligible.



Bomb cooks—poplar lot 6. Temp. rise, 1°C./min.; cooking temp., 170°C.

Fig. 5. Effect of sulfide charge on rate of pulping

It is shown in Fig. 2 that within the limits of the conditions recorded in Tables III, IV, V, and VI, an increase in the effective alkali charge from 12 to 16% does not adversely affect the lignin-carbohydrate ratio of the pulp at any yield level. It is, however, evident from both Figs. 1 and 2 that the *rates* of solution of both lignin

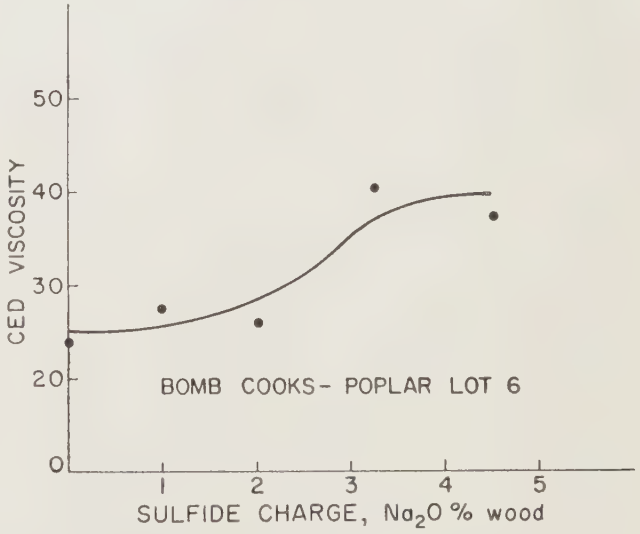
Table VI. Effect of Sulfide Charge at 10% Effective Alkali Charge

Poplar—lot 6—bomb cooks

Cook no.	Time at 170°C., min.	Yield, %	Roe no.	Lignin, %	Pentosan, %
		2% Sulfide Charge			
M 872	0	71.0	16.3	14.3	18.0
M 873	20	67.5	13.0	11.1	17.8
M 874	30	66.2	11.4	10.0	18.1
M 875	45	64.5	11.0	9.3	18.5
M 876	60	64.1	10.3	9.0	18.7
M 877	90	62.1	9.3	8.3	18.4
		4.5% Sulfide Charge			
M 913	0	69.2	16.1	13.8	18.3
M 914	20	65.6	12.3	10.2	18.5
M 915	45	64.5	10.9	9.2	19.0

Constants: Rise-to-temperature—1°C./min.; maximum temperature, 170°C.; liquor-to-wood ratio—4.5:1 (including chip moisture).

and carbohydrate *are* influenced by the liquor composition. In Figs. 3 and 4, the logarithms of lignin-carbohydrate ratio have been plotted against time for each series of digestions, and these show clearly the change in rate with changing liquor composition. Thus, when pure caustic solution is employed the rate of change is constant. When, however, sodium sulfide is added, two rates appear. The first of these is quite distinct, being a function of the sulfide and caustic present in the cook. The second, although appearing similar to that obtained when caustic soda only is present, ceases to be



Effective alkali charge, 12%; temp. rise, 1°C./min.; cooking temp., 170°C.

Fig. 6. Effect of sulfide charge on pulp viscosity

constant when very high effective alkali and sulfide charges, which would not be practical, are used. Thus the break in the rate of composition occurs when approximately one third of the wood substance has gone into solution. This type of graphic representation was first made in studies on the alkaline pulping of western red cedar (*9*).

Table VII. Effect of Temperature

Poplar—lot 6—bomb cooks

Cook no.	Time at 160°C., min.	Yield, %	Roe no.	Lignin, %	Pentosan, %
	Digestion temp.—160°C. Temp. rise 80 min., from 80 to 160°C.				
M 823	16	69.3	15.7	13.2	16.8
M 824	62	64.3	10.3	8.9	17.6
M 825	86	61.7	8.0	6.9	17.9
M 826	120	60.1	5.8	5.3	18.3
M 827	153	58.9	4.7	4.3	18.8
M 828	190	58.4	3.5	3.3	18.9
	Digestion temp.—150°C. Temp. rise 70 min. from 80 to 150°C.				
M 829	55	67.6	14.7	12.8	16.8
M 830	167	62.3	8.1	7.2	17.9
M 831	223	61.1	6.3	5.5	18.5
M 832	314	59.3	4.3	4.7	19.1
M 833	390	58.8	3.4	3.4	19.1
M 834	476	58.0	3.0	2.8	19.1

Constants: Effective alkali charge, 12%; Sulfide charge, 2%; liquor-to-wood ratio—4.5:1 (including chip moisture).

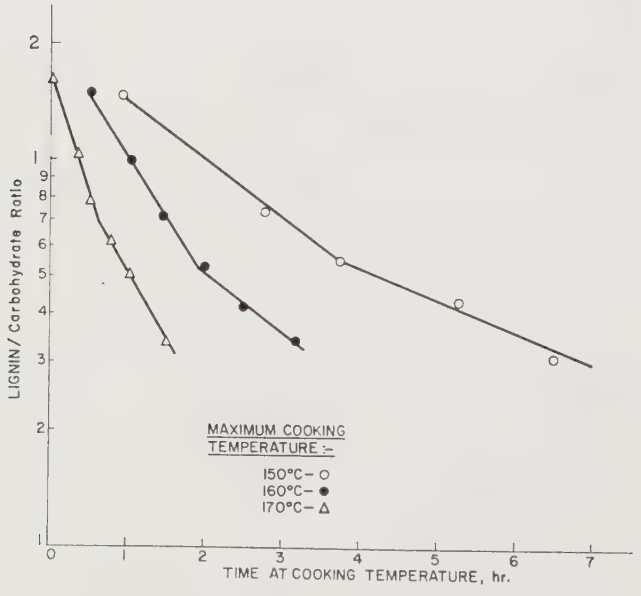
To establish how far, relatively, the rate of change of composition is affected by sulfide and effective alkali charge, the slopes of the primary rate curves in Figs. 3 and 4 have been plotted against sulfide charge and thus the relative rates, as affected by sulfide and effective alkali charge, are given in Fig. 5. From this two facts emerge; the first is that for *poplar* there is a maximum

Table VIII. Effect of Sulfide Charge on Pulp Viscosity

Sulfide charge, Na_2O% wood	0	1	2	3	4.5
Viscosity, CED	24.4	27.5	26.3	40.5	37.5

Constants: Effective alkali charge, 12%; rise-to-temperature—1°C./min.; time at 170°C.—90 min.; liquor-to-wood ratio—4.5:1 (including chip moisture).

rate of delignification, regardless of the amount of effective alkali or sulfide charge used, and the second is that this maximum rate occurs at a lower sulfide charge when the effective charge is increased. In other words, as far as the rate of delignification is concerned, there is an optimum quantity of sulfide above which increases



Bomb cooks—poplar lot 6. Effective alkali charge, 12%; sulfide charge, 2%; temp. rise, 1°C./min. from 80°C.

Fig. 7. Effect of temperature on lignin/carbohydrate ratio

Table IX. Effect of Sulfide Charge

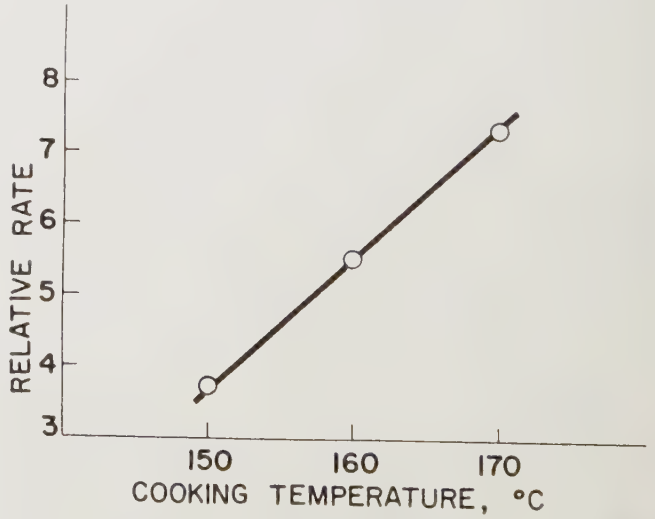
Birch—lot 7—bomb cooks

Cook no.	Time at 170°C., min.	Yield, %	Roe no.	Lignin, %	Pentosan, %	Alpha-residue, %	Resistant pentosan, % alpha-
	0% Sulfide Charge						
M-2 945	0	77.1	23.9	19.0	19.3	92.7	16.0
M-2 946	20	70.2	19.9	16.0	19.7	94.3	16.9
M-2 947	30	68.8	18.4	14.5	20.2	93.5	17.0
M-2 948	45	66.0	16.6	13.2	20.5	93.8	17.5
M-2 949	60	64.3	14.6	11.5	20.6	94.5	18.0
M-2 950	90	62.9	12.8	10.2	21.0	94.5	17.8
	2% Sulfide Charge						
M-2 924	0	71.8	18.7	14.6	20.9	92.8	16.7
M-2 925	20	63.9	11.9	9.3	21.7	91.6	17.2
M-2 930	30	62.8	10.5	9.0	22.3	92.3	17.5
M-2 927	45	61.0	7.7	6.8	22.7	92.5	18.7
M-2 928	60	58.2	5.8	5.1	23.1	92.2	18.2
M-2 929	90	56.1	3.6	3.4	23.4	91.5	17.9
	4.5% Sulfide Charge						
M-2 939	0	70.0	17.5	13.5	21.8	92.1	16.6
M-2 940	20	62.8	8.8	6.9	23.0	92.3	18.9
M-2 941	30	58.3	5.7	4.6	23.7	91.1	18.4
M-2 942	45	58.2	4.2	3.6	24.1	89.0	17.3
M-2 943	60	56.8	3.4	2.5	23.9	88.6	16.1
M-2 944	90	55.0	2.7	2.3	24.0	89.7	17.4
	12% Sulfide Charge						
M-2 898	0	64.7	11.9	9.8	21.6	91.7	17.0
M-2 901	10	60.1	6.4	5.5	22.7	88.0	15.4
M-2 899	20	58.7	4.0	3.4	22.7	86.0	13.4
M-2 900	30	57.2	3.6	3.4	22.3	86.5	13.7
M-2 902	60	55.6	3.5	3.0	22.2	85.5	12.5
M-2 903	90	54.2	3.4	3.0	22.2	84.8	11.5

Constants: Effective alkali charge, 12%; rise-to-temperature—1°C./min., maximum temperature, 170°C.; liquor-to-wood ratio—4.5:1 (including chip moisture).

in the sulfide have no effect. This optimum value is reduced as the effective alkali charge, or the alkalinity of the liquor, is increased. Data from Hagglund's work (*21*) on spruce, when plotted in this manner, show similar trends which are illustrated in Fig. 10b.

Table VIII gives the viscosities of the pulps produced by using varying amounts of sulfide at constant effective alkali charge. These data, plotted in Fig. 6, indicate that viscosity increases sharply at the point where the maximum rate of delignification initially occurs (see Fig. 5) but that, beyond this point, increasing

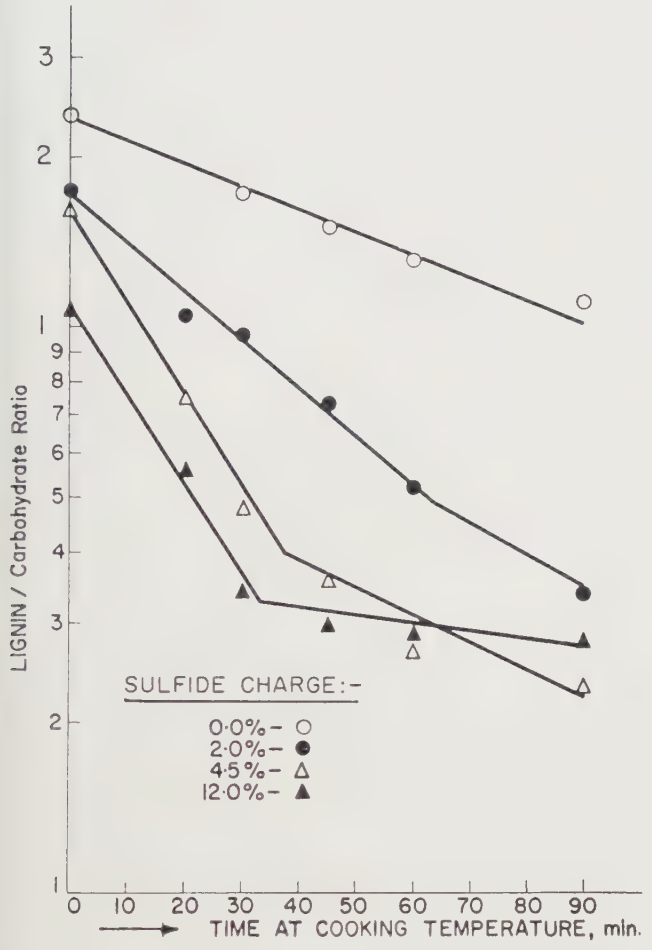


Bomb cooks—poplar lot 6. Effective alkali charge, 12%; sulfide charge, 2%; temp. rise, 1°C./min.

Fig. 8. Effect of cooking temperature on rate of pulping

sulfide charge ceases to affect it. Thus it may be concluded that a certain optimum amount of sulfide is required, not only to obtain the maximum rate of delignification during the kraft cook, but to maintain a high viscosity as well.

The influence of temperature upon the reaction for the limited data obtained, and given in Table VII, is



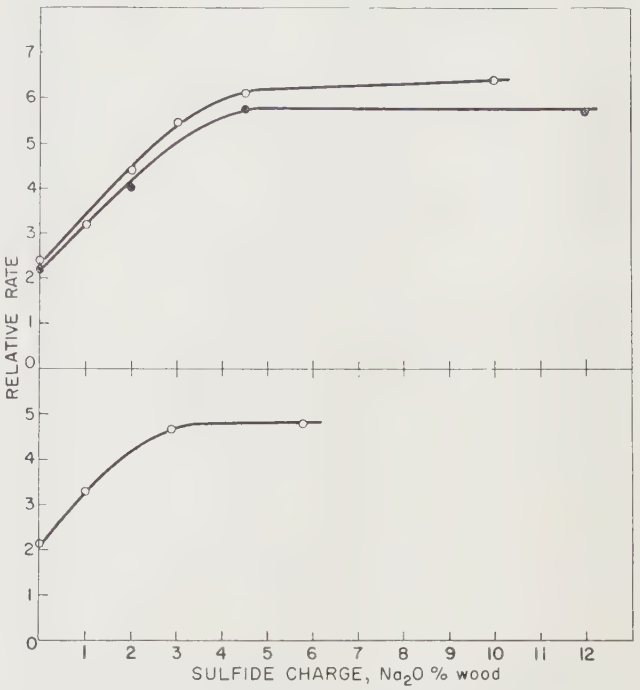
Bomb cooks—birch lot 7. Effective alkali charge, 12%; temp. rise, 1°C./min.; cooking temp., 170°C.

Fig. 9. Effect of sulfide charge on lignin/carbohydrate ratio

illustrated in Figs. 7 and 8. An apparent straight-line relation will be observed between the temperature and relative delignification rate.

From parallel experiments carried out on birch, given in Table IX and plotted in Figs. 9 and 10a, it was found, given the same cooking conditions, the delignification trends of birch and poplar are extremely similar and appear, in fact, identical at low sulfide charges (0 to 2%). When we bear in mind that the woods are morphologically quite dissimilar, this close similarity in their reactions to alkaline liquors suggests that morphology does not play an important role in delignification in the kraft process.

The carbohydrates in wood are solubilized during the kraft cook. Figure 11 illustrates how this is influenced by sulfide charge. It will be observed that the curves for pentosan and alpha-cellulose, when plotted against residual lignin in pulp, exhibit similar trends (the alpha-cellulose, in this instance, having been corrected for lignin and resistant pentosans). Thus, both pentosans and alpha-cellulose are, during cooking, removed in a regular manner, *regardless* of the sulfide charge, until the pulp contains about 3% residual lignin, or when some 80% of the lignin in the wood has been removed. As the amount of residual lignin decreases below 3%, proportionally more carbohydrate is removed. This change in trend



(a) (Above) Bomb cooks—birch lot 7, poplar lot 6. Effective alkali charge, 12%; temp. rise, 1°C./min.; cooking temp., 170°C. (b) (Below) Spruce—Hagglund, Hedlund. Active alkali charge, 18.75%.

Fig. 10. Effect of sulfide charge on rate of pulping

coincides with the point at which the rate of change of composition diminishes (see Fig. 9). For it to occur, however, not more than 4.5% sulfide must be used below the 3% residual lignin level.

It will be noted that for the same alkalinity and cooking time, i.e., with the same expenditure of energy, the solubilization of both alpha-cellulose and pentosans, within the limits of their determinations, become less with decreasing sulfide charge. For any given time, in fact, it becomes least when the sulfide is absent entirely although, of course, the degree of delignification is correspondingly less. Alternatively, when cooking down to the same low lignin content, the presence of the sulfide accelerates the reaction and, it might be said, exercises a greater selectivity for lignin and exerts a protective influence over the two carbohydrates measured. This "protective" influence is further evident in the drop in viscosity, noted previously, which accompanies decreasing sulfide charge.

Two-Cu. Ft. Cooks

To study the effect of the pulping variables on pulp strengths, a series of digestions on a 2-cu. ft. scale were carried out. For the initial study of the cooking variables two levels (2 and 4.5%) of sulfide charge were used, two levels (12 and 14%) of effective alkali charge, and 3 temperatures, 150, 160, and 170°C.

Table X. Cooking Variables and Pulp Properties

Poplar—lot 3—2 cu. ft. cooks

Cook no.	Cook time, min. To	Cook time, min. At	Blow temp., °C.	Total yield, %	Chemical properties of pulp: TAPPI lignin, %	Chemical properties of pulp: Pentosans, %	Chemical properties of pulp: Bleached α-Cell.	Chemical properties of pulp: Bleached CED visc.	Physical properties of pulp (300 ml. C.S. freeness): Initial brightness, G.E.	Time, min.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.
Constants: effective alkali charge, 12%; sulfide charge, 2%; liquor-to-wood ratio—4:1 (excluding chip moisture)														
1007	45	90	170	59.4	1.8	18.4	84.3	35	31.6	47	1.24	65	0.64	10900
1008	45	67 1/2	170	59.9	2.4	18.2	84.2	41	28.1	48	1.25	66	0.59	11100
1025	45	56	170	59.1	2.5	18.2	84.2	41	29.6	40	1.30	61	0.74	10700
1010	45	45	170	61.1	3.4	18.3	83.5	44	27.8	55	1.26	66	0.65	10900
1014	45	22 1/2	170	64.3	7.6	17.9	83.0	66	21.1	55	1.20	61	0.68	10500
1101B	45	12 1/4	170	65.7	9.0	17.3	87.8	63	21.1	55	1.20	61	0.51	10500
1015	45	0	170	70.7	13.0	16.2	81.3	81	18.0	56	1.27	53	0.70	9800
1023	40	0	160	74.0	15.7	16.0	79.9	..	21.4	47	1.37	47	0.70	8500
1020	35	0	150	77.4	16.9	16.3	79.6	..	22.7	70	1.38	46	0.69	8200
1019	22 1/2	0	125	81.2	18.2	17.2	76.3	..	29.6	68	1.40	42	0.63	7500
1024	10	0	100	85.6	18.5	18.2	73.5	..	37.6	43	1.48	36	0.58	6800
Constants: effective alkali charge, 14%; sulfide charge, 2%														
1088A	45	90	170	59.1	1.4	17.8	89.0	30	34.4	35	1.29	62	0.74	9800
1089A	45	0	170	69.1	13.0	15.7	87.1	78	22.5	43	1.32	54	0.67	9000
1091A	35	0	150	76.9	16.5	16.2	84.7	..	27.6	51	1.39	62	0.65	8100
Constants: effective alkali charge, 12%; sulfide charge, 4.5%														
1081A	45	90	170	58.6	1.1	17.7	88.0	45	37.0	35	1.28	74	0.75	10200
1085A	45	0	170	67.5	10.6	16.9	86.1	74	21.2	42	1.33	58	0.67	8900
1082A	30	0	140	78.5	17.6	18.4	87.0	..	26.9	51	1.39	50	0.67	7900
Constants: effective alkali charge, 12%; sulfide charge, 2%														
1093A	40	210	160	59.8	1.4	18.6	...	37	34.4	35	1.30	68	0.70	11100
1095A	40	34 3/4	160	67.5	9.4	17.3	...	66	21.9	38	1.28	60	0.60	10000
1096A	35	533	150	59.6	2.3	18.5	...	33	30.5	32	1.23	60	0.73	10300
1099A	35	96	150	68.0	9.9	17.1	...	64	21.2	37	1.28	59	0.64	9400

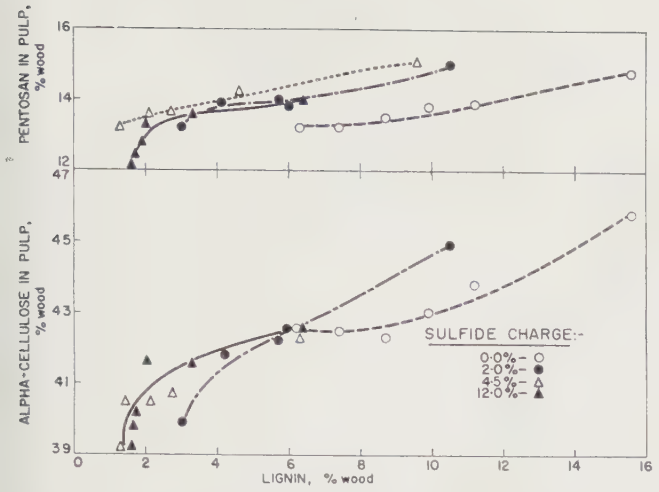
The effects of cooking variables on the physical properties of pulp are given in Tables X and XI and are shown in Figs. 12, 13, and 14, where pulp strengths are plotted against residual lignin. These show that at low lignin values, e.g., below 6%, pulp strengths, brightness, and viscosity are improved by an increase in sulfide charge from 2 to 4.5% while using 12% effective alkali charge. This agrees with the conclusions drawn from the bomb-scale work: this showed that 2% sulfide charge was a marginal amount, and that the viscosity increased when the charge was raised to 4.5%.

An increase in the alkalinity of the liquor or, alternatively, an increase of from 12 to 14% effective alkali

Table XI. Cooking Variables and Pulp Properties

Poplar—lot 4—2 cu. ft. cooks

Cook no.	Cook time, min. To	Cook time, min. At	Blow temp., °C.	Total yield, %	Chemical properties of pulp: TAPPI lignin, %	Chemical properties of pulp: Pentosans, %	Chemical properties of pulp: Bleached α-Cell.	Chemical properties of pulp: Bleached CED visc.	Physical properties of pulp (300 ml. C. S. freeness): Initial brightness, G.E.	Time, min.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.
Constants: effective alkali charge, 12%; sulfide charge, 2%; liquor-to-wood ratio—4:1 (excluding chip moisture)														
1031	45	90	170	57.5	1.9	19.1	87.0	41.0	31.5	43	1.27	50	0.79	10600
1034	45	57 1/2	170	56.7	2.3	19.2	86.8	42.4	30.5	39	1.26	68	0.71	11000
1035	45	45	170	58.9	3.3	18.9	88.4	45.3	27.1	40	1.29	59	0.71	10100
1038	45	22 1/2	170	61.2	6.5	18.4	85.8	61.0	24.2	40	1.29	60	0.70	9900
1039	45	12 1/4	170	64.4	10.1	18.3	84.2	70.8	20.0	36	1.24	57	0.70	9300
1030	45	6	170	67.8	11.7	16.8	84.5	...	18.1	51	1.26	57	0.68	9900
1042	45	0	170	68.8	13.6	17.7	82.4	...	20.2	37	1.29	53	0.71	8800
1043	40	0	160	73.3	16.1	17.4	80.4	...	22.3	51	1.34	50	0.70	8300
1045	35	0	150	74.9	17.6	17.6	80.5	...	27.7	61	1.41	42	0.62	7900
1047	27 1/2	0	135	79.3	18.2	18.3	76.9	...	29.1	62	1.43	46	0.58	7900
1048	22 1/2	0	125	80.1	18.6	18.7	76.0	...	24.1	63	1.37	43	0.59	8250
1049	15	0	110	82.5	18.7	19.1	73.1	...	33.6	65	1.46	38	0.56	7350
1051	10	0	100	84.3	18.7	19.4	72.6	...	35.5	64	1.50	37	0.60	7250
Constants: effective alkali charge, 14%; sulfide charge, 2%														
1088B	45	90	170	56.5	1.9	19.1	87.0	41.2	33.4	31	1.25	60	0.77	9800
1091B	35	0	170	74.3	17.4	16.9	80.0	...	26.4	51	1.37	61	0.65	8700
Constants: effective alkali charge, 12%; sulfide charge, 4.5%														
1081B	45	90	170	56.5	1.5	18.4	87.0	47.7	35.3	22	1.30	68	0.83	10200
1082B	35	0	170	76.4	18.2	17.4	81.4	...	27.0	38	1.41	44	0.63	8400
Constants: effective alkali charge, 12%; sulfide charge, 2%														
1093B	40	210	160	57.1	1.4	17.8	87.0	41.0	33.8	28	1.26	65	0.73	11100
1095B	40	34 3/4	160	65.9	10.0	18.0	83.0	...	20.6	35	1.25	56	0.64	9400

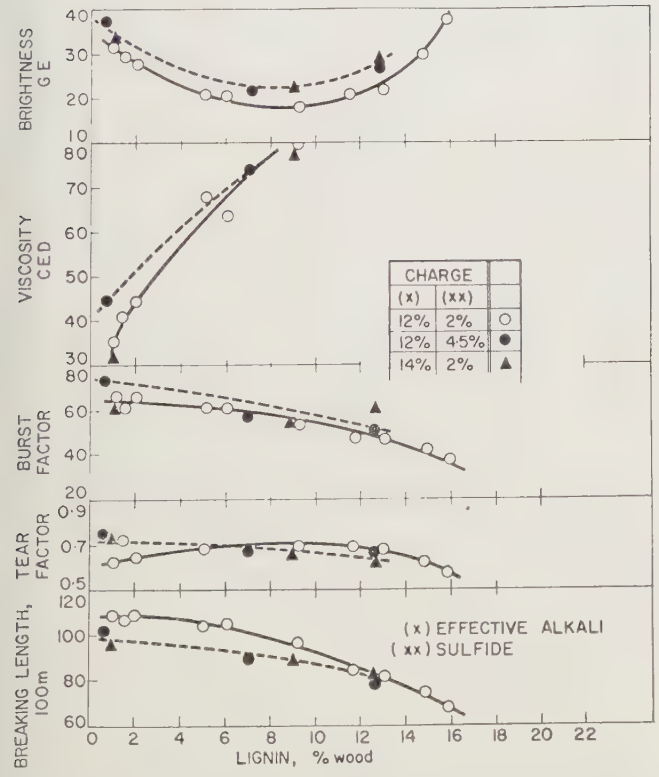


Bomb cooks—Birch lot 7. Effective alkali charge, 12%; temp. rise, 1°C./min; cooking temp., 170°C.

Fig. 11. Effect of sulfide charge on carbohydrate removal

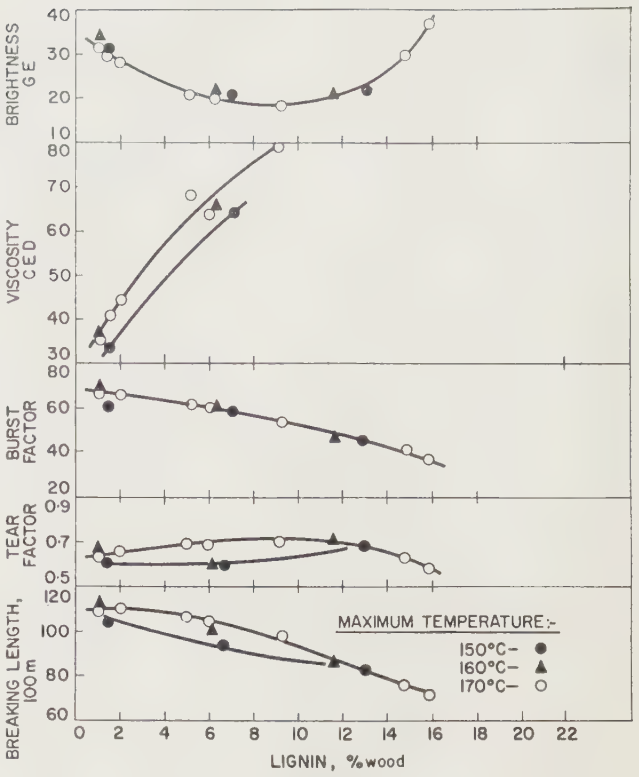
charge, degrades the pulp quality in every respect except brightness. Thus, although the bomb cooks indicate no effect on the lignin-carbohydrate ratio, by increasing the alkalinity of the liquor, it appears that pulp strengths *are* impaired. Above 6% residual lignin, i.e., about 65% yield, the variations in cooking liquor composition were insufficient to effect any perceptible change in pulp strengths. Increasing the sulfide charge or effective alkali charge reduces beating time to 300 ml. C.S. freeness, at which all pulp strengths are compared.

Higher cooking temperatures, within the limits of the experiment, do not appear to undermine the



2 cu. ft. cooks—poplar lot 3. Temp. rise, 2°C./min.; cooking temp., 170°C.

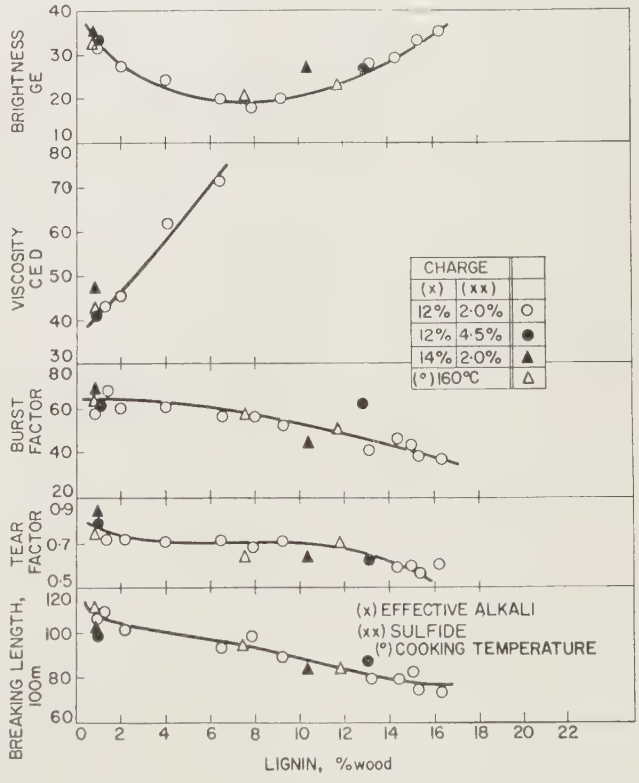
Fig. 12. Effect of effective alkali and sulfide charge on pulp properties (300 ml. C.S. freeness)



2 cu. ft.—poplar lot 3. Effective alkali charge, 12%; sulfide charge, 2%; temp. rise, 2°C./min.

Fig. 13. Effect of cooking temperature on pulp properties (300 ml. C.S. freeness)

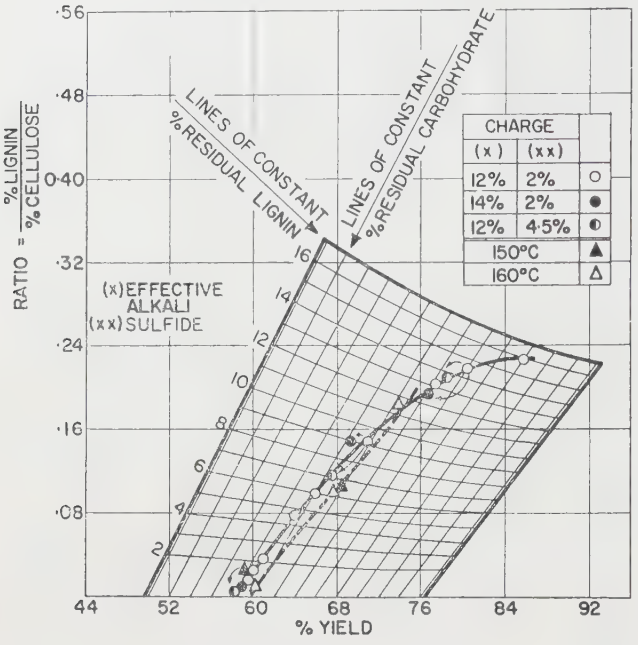
physical properties of the pulp; in fact, at these temperatures, owing to the shorter exposure time of the carbohydrates to the alkaline liquors, pulp strengths are higher when compared at the same residual lignin.



2 cu. ft. cooks—poplar lot 4. Temp. rise, 2°C./min.; max. cooking temp., 170°C.

Fig. 14. Effect of effective alkali and sulfide charge on pulp properties (300 ml. C.S. freeness)

By following the change in pulp composition and the concomitant variation in yield, the effects of cooking variables are effectively illustrated using the Ross diagram (*22*). Thus, Fig. 15 shows a curve obtained with one sample of poplar under set conditions of cooking and also the effects of the cooking variables. The arrows on the diagram indicate trends of the



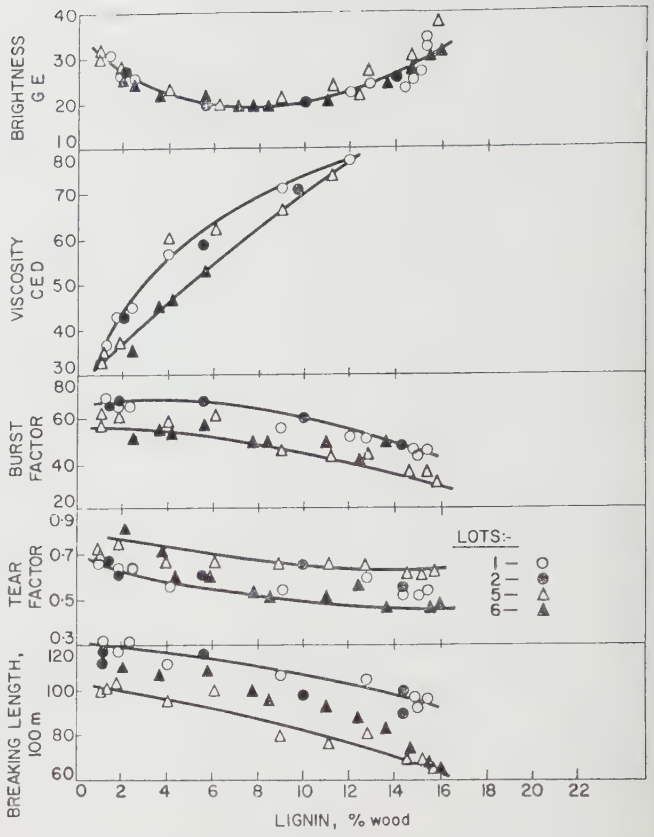
2 cu. ft. cooks—poplar lot 4. Temp. rise from 80°C.—2°C./min.; max. cooking temp., 170°C.

Fig. 15. Change of pulp composition versus yield

pulping reaction which result from changes in cooking conditions. Thus, by increasing the effective alkali charge from 12 to 14% while maintaining a constant sulfide charge of 2%, the pulping line moves very slightly to the left of the diagram, indicating a small increase in the lignin-carbohydrate ratio at the same yield. Conversely, with a reduction in cooking temperature from 170 to 160°C., this ratio has decreased for the same yield, showing a slightly improved selectivity for lignin removal at the lower temperature.

Increasing the sulfide charge from 2 to 4.5%, although it increased the rate of pulping, did not increase selectivity for lignin. As a result this increase in sulfide has only moved the relative point further down the curve. Had less than the marginal sulfide charge of 2% been used, the curve would have moved to the left, as indicated in the bomb-scale studies. Therefore, what was concluded from the bomb-scale work about the effect of the cooking variables on pulp properties and pulping rate was, in the main, confirmed by the 2 cu. ft. digester-scale work.

One cooking variable which has received comparatively little attention in the past is the changing nature of the wood. It is known that differences in pulping and papermaking properties exist not only between trees from different species, but between those of the same species. These differences can be traced to such factors as the tree's composition, its environment, and a multiplicity of other factors, affecting growth. To determine the size and range of variations within the

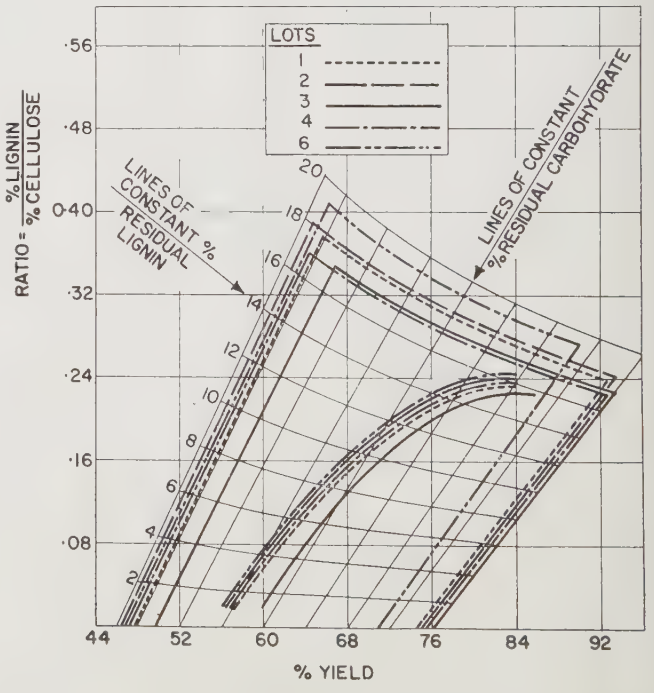


2 cu. ft. cooks—poplar lots 1, 2, 5, 6. Effective alkali charge, 12%; sulfide charge, 2%; temp. rise, 2°C./min.; max. cooking temp., 170°C.

Fig. 16. Properties of pulp from different samples of the same species

same species, samples of the same species of poplar, grown in different localities, were subjected to identical pulping treatments.

In Fig. 16 the physical properties of the pulps obtained from the pulping of various samples (the proces-



Poplar lots 1, 2, 3, 4, and 6. Effective alkali charge, 12%; sulfide charge, 2%; temp. rise, 2°C./min.; max. cooking temp., 170°C.

Fig. 17. Change of pulp composition versus yield.

Table XII. Cooking Variables and Pulp Properties

Poplar—lot 6—2-cu. ft. cooks

Cook no.	Cook time, min. To	Cook time, min. At	Blow temp., °C.	Total yield, %	Chemical properties of pulp: TAPPI lignin, %	Pento-sans, %	Bleached α-Cell.	Bleached CED visc.	Physical properties of pulp (300 ml. C.S. freeness): Initial brightness, G.E.	Time, min.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.
925	45	90	170	57.3	3.6	19.5	86.2	42.9	25.1	44	1.30	60	0.81	11000
938	45	67 1/2	170	57.8	4.4	19.3	82.5	34.9	24.3	40	1.35	50	0.72	8900
933	45	45	170	59.6	6.3	18.7	81.6	44.6	21.8	44	1.39	55	0.60	10650
942	45	35	170	60.9	6.7	18.1	83.1	46.0	23.8	38	1.43	55	0.60	10000
934	45	22 1/2	170	62.8	9.0	18.3	81.0	52.9	21.2	43	1.23	58	0.53	10800
935	45	12 1/4	170	65.4	11.7	17.9	80.1	...	19.6	34	1.32	50	0.55	9800
943	45	6	170	67.9	12.6	17.0	81.2	...	19.7	38	1.32	50	0.50	9500
936	45	0	170	69.9	15.7	16.7	79.8	...	20.2	44	1.34	49	0.52	9200
939	40	0	160	73.1	17.0	17.5	79.3	...	21.7	42	1.38	42	0.57	8700
937	35	0	150	75.4	18.1	17.7	77.7	...	23.6	49	1.44	49	0.46	8100
927	22 1/2	0	125	79.0	18.5	18.4	76.6	...	27.5	52	1.51	36	0.56	7400
940	15	0	110	81.5	19.2	19.1	75.4	...	31.2	51	1.58	32	0.46	6800
951	10	0	100	83.8	19.2	19.1	73.9	...	31.0	58	1.59	29	0.47	6500

Constants: effective alkali charge, 12%; sulfide charge, 2%; liquor-to-wood ratio—4:1 (excluding chip moisture).

sing conditions of which are given in Tables XII, XIII, XIV and XV), are plotted against their residual lignin contents, and in Fig. 17 the pulping trends of the samples are illustrated on the Ross diagram. It will be seen that the pulping properties and the physical properties of the pulps vary considerably within the samples under test. The order of magnitude of the differences is greater than that manifest from any change in processing conditions. The strength properties vary as much as 20% throughout the whole yield range, and there is, moreover, at the same lignin content, a 4% yield difference among the samples processed.

One interesting observation is that the chemical analyses of the wood samples, indicated as limiting boundaries on the Ross diagram, are displaced by approximately the same degree as the pulping curve for each wood.

Table XVII shows the characteristics of the different samples of poplar in decreasing order of wood density and compares them with a sample of birch which has been subjected to the same digestion and processing conditions seen in Table XVI. The data in this table indicate that the alpha-cellulose in the pulp, after correction for lignin and resistant pentosan, decreases with decreasing wood density. Of greater importance, however, is the fact that this corrected value for alpha-cellulose in the pulp is always in constant proportion to both the total yield during kraft cooking and to the "alpha" determined from the holocellulose in the original wood. This relationship holds true for all samples or species of hardwoods tested.

Figure 18 plots, for all the poplar and birch samples used in this work, the amounts of pentosan and lignin lost during the cooking, against yield. An interesting feature of this is that of the pentosan solubilized

Table XIII. Cooking Variables and Pulp Properties

Poplar—lot 5—2-cu. ft. cooks

Cook no.	Cook time, min. To	Cook time, min. At	Blow temp., °C.	Total yield, %	Chemical properties of pulp: TAPPI lignin, %	Pento-sans, %	Bleached α-Cell.	Bleached CED visc.	Physical properties of pulp (300 ml. C.S. freeness): Initial brightness, G.E.	Time, min.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.
1052	45	90	170	58.0	1.7	19.3	83.1	32.3	30.3	30	1.26	59	0.72	9900
1053	45	67 1/2	170	58.5	1.8	19.3	85.4	34.5	30.6	27	1.29	61	0.71	10100
1055	45	45	170	58.9	3.0	18.9	86.4	37.1	28.1	31	1.30	62	0.75	10300
1059	45	22 1/2	170	62.8	6.3	18.0	84.4	60.6	23.4	36	1.25	58	0.67	9450
1060	45	12 1/4	170	64.9	9.4	17.1	85.1	62.4	19.2	30	1.29	61	0.67	10100
1061	45	0	170	69.6	13.0	16.7	84.4	67.4	21.3	44	1.34	45	0.67	7900
1062	40	0	160	73.0	15.4	16.6	82.5	74.4	23.7	35	1.37	43	0.67	7600
1065	35	0	150	76.0	16.9	16.7	80.3	...	26.7	41	1.36	44	0.66	8000
1066	22 1/2	0	125	79.6	18.3	17.5	78.2	...	30.4	60	1.45	36	0.61	7000
1068	15	0	110	83.6	18.3	18.4	75.0	...	34.3	56	1.49	35	0.60	6800
1069	10	0	100	85.8	18.5	18.3	72.8	...	38.8	76	1.57	31	0.63	6500

Constants: effective alkali charge, 12%; sulfide charge, 2%; liquor-to-wood ratio—4:1 (excluding chip moisture).

Table XIV. Cooking Variables and Pulp Properties

Poplar lot 2—2-cu. ft. cooks

Cook no.	Cook time, min. To	Cook time, min. At	Blow temp., °C.	Total yield, %	Chemical properties of pulp: TAPPI lignin, %	Pento-sans, %	Bleached α-Cell.	Bleached CED visc.	Physical properties of pulp (300 ml. C.S. freeness): Initial brightness, G.E.	Time, min.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.
981	45	90	170	56.5	2.3	18.6	83.1	38.1	31.0	37	1.20	69	0.62	11800
984	45	67 1/2	170	57.7	2.5	18.8	81.8	38.8	33.9	41	1.25	66	0.67	11200
989	45	56	170	58.6	3.2	18.7	82.2	39.2	29.9	40	1.23	69	0.61	12100
1101A	45	12 1/4	170	62.8	8.9	17.7	80.4	50.1	23.3	32	1.26	68	0.61	11600
1087	45	0	170	69.4	14.4	17.0	78.2	...	21.6	31	1.25	61	0.66	9800
1102A	22 1/2	0	125	78.6	18.3	16.8	76.0	...	31.1	50	1.38	49	0.55	8900

Constants: effective alkali charge, 12%; sulfide charge, 2%; liquor-to-wood ratio—4:1 (excluding chip moisture).

Table XV. Cooking Variables and Pulp Properties

Poplar—lot 1—2-cu. ft. cooks

Cook no.	Cook time, min. To	Cook time, min. At	Blow temp., °C.	Total yield, %	Chemical properties of pulp: TAPPI lignin, %	Pentosans, %	Bleached: α-Cell.	Bleached: CED visc.	Physical properties of pulp (500 ml. C.S. freeness): Initial brightness, G.E.	Time, min.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.
966	45	90	170	57.7	2.2	17.2	85.3	36.9	30.1	40	1.18	70	0.67	12300
968	45	67 1/2	170	59.0	3.0	17.1	83.2	43.0	26.7	41	1.24	65	0.62	11900
967	45	45	170	59.6	3.9	17.3	85.3	44.8	25.5	49	1.23	66	0.53	12200
969	45	22 1/2	170	62.0	6.6	16.9	84.8	51.4	23.1	48	1.25	63	0.55	11200
993	45	6	170	65.2	11.0	16.4	81.2	58.4	...	..	...	..	...	...
971	45	0	170	68.7	13.2	16.3	81.3	70.9	20.2	54	1.23	57	0.55	10700
972	40	0	160	72.3	16.5	15.8	79.1	77.9	22.1	49	1.31	52	0.59	10300
973	35	0	150	74.1	17.1	15.8	78.8	...	24.4	51	1.30	51	0.60	10500
994	27 1/2	0	135	78.1	18.3	16.8	77.2	...	23.6	73	1.31	48	0.52	10000
995	22 1/2	0	125	80.7	18.4	17.5	76.7	...	25.8	71	1.34	47	0.54	9650
996	15	0	110	81.4	18.5	18.0	74.2	...	26.7	68	1.21	44	0.52	9300
997	10	0	100	83.0	18.6	18.1	73.6	...	34.4	73	1.38	46	0.54	9600

Constants: Effective alkali charge, 12%;
Sulfide charge, 2%;
Liquor-to-wood ratio—4:1 (excluding chip moisture).

during the digestion process, some 90% is lost before the cooking temperature (170°C.) is reached. Meanwhile, only about half of the lignin eventually solubilized is removed. Since these conditions can, within practical limits, be only slightly improved by an increase in sulfide charge, this would seem to be a very good illustration of the shortcomings of the kraft liquor as a delignifying medium. This has also been illustrated by Yllner and co-workers (*24*) in a recent paper.

It will also be seen from Fig. 18 that, regardless of the amount of lignin present in the original wood, the proportion of it removed during cooking remains the same. This is true of pentosan, however, for only five samples tested; there are deviations for the other two. However, in this case the Ross diagram (Fig. 19) does not show up the proportionality of the reaction with all the woods as definitely. It must be mentioned at the same time that the physical characteristics of birch were greatly superior to those of the strongest poplar pulp shown in Fig. 20. In spite, however, of any morphological or chemical differences in the original trees, it still seems to remain true that the wood constituents are all removed in the same proportion. Further work is necessary, however, to confirm this.

There is no direct evidence in the present work to indicate what environmental cause brought about the differences within the samples and species under investigation. A prerequisite for future work would therefore be careful sampling and detailed tree analysis before cutting.

CONCLUSIONS

The preliminary studies indicated that a certain optimum sulfide charge is necessary to obtain maximum rate of delignification while maintaining viscosity. This maximum rate is always the same, regardless of

Table XVI. Cooking Variables and Pulp Properties

Birch—lot 7—2-cu. ft. cooks

Cook no.	Cook time, min. To	Cook time, min. At	Blow temp., °C.	Total yield, %	Chemical properties of pulp: TAPPI lignin, %	Pentosans, %	α-Res., %	Res. pent., % α-res.	Physical properties of pulp (300 ml. C.S. freeness): Initial brightness, G.E.	Time, min.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.
Constants: effective alkali charge, 12%; sulfide charge, 2%; liquor-to-wood ratio—4:1 (excluding chip moisture)														
1127	45	90	170	57.4	3.8	23.1	86.1	13.6	22.9	40	1.30	77	0.97	11300
1128	45	67 1/2	170	58.5	3.9	23.7	86.9	14.5	22.2	41	1.30	74	0.98	11400
1130	45	56	170	58.1	4.2	22.6	90.8	17.4	22.4	38	1.29	74	0.92	11800
1131	45	45	170	59.8	6.1	22.9	90.7	16.7	18.9	36	1.28	74	0.87	11500
1133	45	22 1/2	170	61.2	8.6	21.6	91.2	16.5	16.7	45	1.36	78	0.86	11700
1136	45	12 1/4	170	62.0	9.3	22.1	90.8	17.2	16.6	39	1.33	72	0.84	11200
1213	45	6 1/2	170	63.1	10.3	22.0	92.7	16.2	17.9	50	1.31	75	0.84	11200
1137	45	0	170	68.9	13.8	20.0	92.9	16.0	17.8	43	1.37	66	0.78	10800
1141	40	0	160	73.0	17.6	20.0	92.6	16.3	18.1	64	1.52	59	0.85	9600
1209	35	0	150	74.9	18.5	20.0	92.0	16.1	22.3	66	1.41	51	0.81	9200
1139	22 1/2	0	125	79.8	20.3	21.9	91.7	16.8	25.3	65	1.69	42	0.76	8100
1143	10	0	100	85.1	20.1	22.9	87.6	14.3	29.6	54	1.75	33	0.76	6800
Constants: effective alkali charge, 12%; sulfide charge, 4.5%														
1152	45	90	170	56.0	2.4	23.3	87.3	14.8	28.8	34	1.38	82	1.00	12200
1150	45	0	170	65.7	12.5	22.2	91.9	16.2	16.4	54	1.38	60	0.92	10250
1149	40	0	160	72.2	17.3	20.2	92.5	14.9	17.8	61	1.60	50	0.93	8800
1148	35	0	150	73.8	18.1	20.0	92.0	14.9	19.7	66	1.56	46	0.90	8900
Constants: effective alkali charge, 14%; sulfide charge, 2%														
1160	45	90	170	54.8	2.5	23.2	87.9	15.0	29.6	37	1.34	84	0.96	12500
1158	45	0	170	67.3	13.6	20.5	94.1	17.7	18.1	55	1.39	69	0.89	11000
1157	40	0	160	71.0	17.3	20.3	94.6	17.2	19.6	69	1.50	62	0.96	9900
1154	35	0	150	74.1	19.2	20.0	93.5	16.2	20.8	67	1.64	49	0.91	8700

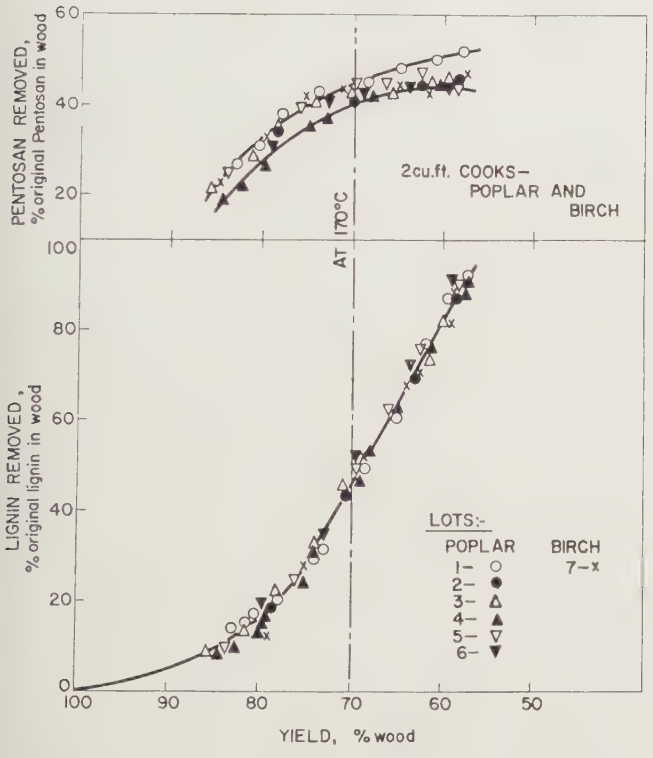
the amount of effective alkali used in cooking. However, at a higher effective alkali charge the same maximum rate is obtained with a lower sulfide charge. Higher alkalinity of the liquor, lower sulfide charge, and lower cooking temperatures adversely affect pulp

Table XVII. Properties of Birch and Poplar Samples

Sample lot no. / *Basic density, g./cc.*	*Poplar* 3 0.406	4 0.393	5 0.390	2 0.368	1 0.356	*Birch* 7 0.530
Kraft Pulps						
Yield, %	59.4	57.5	58.0	56.5	57.7	57.7
Lignin, % pulp	1.8	1.9	1.7	2.3	2.2	3.8
Pentosan, % pulp	18.4	19.1	19.3	18.6	17.2	23.1
α-Residue, % pulp	86.1	83.4	83.3	83.4	81.5	86.1
Resis. pentosan, % α-residue	10.7	9.3	7.0	8.0	7.7	13.6
α-Cell. (corr. for res. pentosan), % wood	44.1	42.9	44.2	42.6	40.9	42.8
Viscosity, CED	35.0	41.0	32.3	38.1	36.9	...
Residual α-cell., % α in original wood	88.5	90.5	92.0	89.0	88.0	89.7
Residual α-cell., % yield	74.0	74.0	75.7	74.0	73.0	74.0

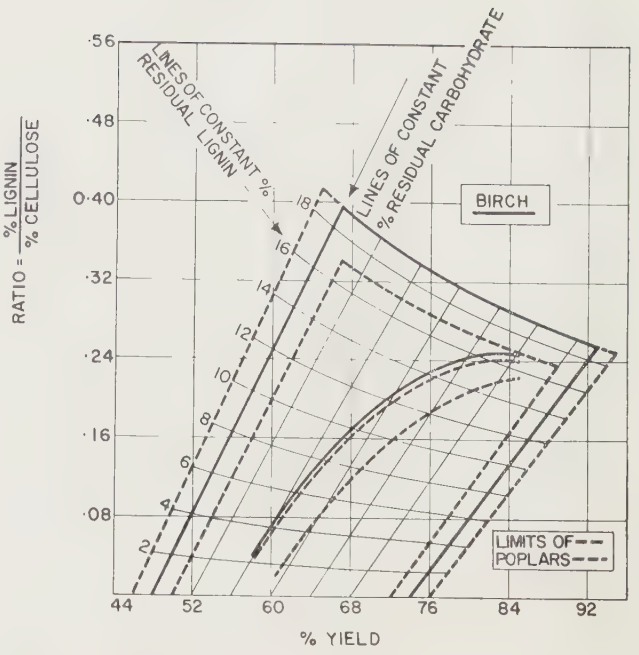
strengths and viscosity. This enlarges upon the findings with western red cedar (*9*), in that the effects of increasing sulfide charge beyond a certain limit have now been determined.

Close similarity was found between the relative pulping rates of poplar and birch. Moreover, certain evidence indicated that the wood constituents are removed during the kraft cooking in constant proportion to the amounts present in the original wood, regardless of the variation within the same species or between different hardwood species. Indications from current Institute work continuing the studies of the alkaline process are that this might also be true of softwood species. The studies also showed that the variations in pulping properties and pulp qualities within the same poplar species were of greater magnitude than those differences manifest from any other cooking variable.



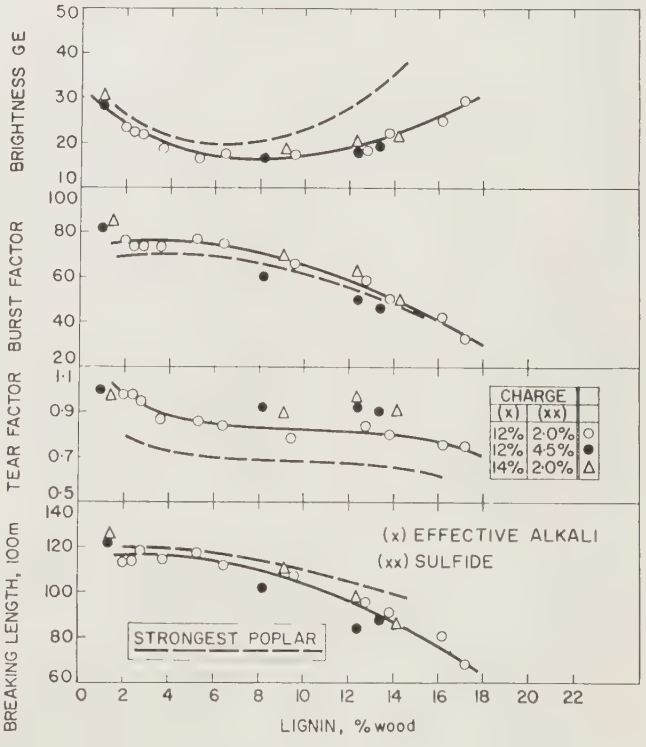
Effective alkali charge, 12%; sulfide charge, 2%; temp. rise, 2°C./min.; max. cooking temp., 170°C.

Fig. 18. Lignin and pentosan removed versus yield


RATIO = % LIGNIN / % CELLULOSE
LINES OF CONSTANT % RESIDUAL LIGNIN
LINES OF CONSTANT % RESIDUAL CARBOHYDRATE
BIRCH
LIMITS OF POPLARS
% YIELD

Effective alkali charge, 12%; sulfide charge, 2%; temp. rise, 2°C./min.; maximum cooking temp., 170°C.

Fig. 19. Change of pulp composition versus yield (comparison between hardwoods)



2 cu. ft. cooks—birch lot 7. Temp. rise, 2°C./min.; max. cooking temp., 170°C.

Fig. 20. Effect of effective alkali and sulfide charge on pulp properties (300 ml. C.S. freeness)

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Grateful acknowledgment is made to J. H. Ross for his assistance and guidance and the encouragement received from the Alkaline Pulping Committee of the Technical Section, Canadian Pulp and Paper Association.

Received Nov. 9, 1959. Presented at the 13th Alkaline Pulping Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Nov. 4–6, 1959.

Effect of Surface Active Agents on Drainage and Physical Strength Properties of Sulfite Pulp

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An investigation has been made to determine the effects of surface active agents on drainage and physical strength properties of sulfite pulp. The surfactants were added in various concentrations to the pulp after the pulp had been beaten to a freeness of 500 ml. in a Tappi Standard beater. The effect of surfactants on drainage was studied by two methods. In the first method, Canadian Standard freeness was taken of the pulp to which surfactant had been added and these values were compared with a blank. Freeness values increased when a cationic surfactant was added to the pulp and decreased when an anionic and a nonionic surfactant was used. In the second method, pulp in suspension was added to a Noble and Wood sheet machine, and each sheet formed, was left in the mold for the same length of time. The weight of the resulting sheets containing surfactants was compared with blanks. All surfactants used facilitated water removal from the sheet. Physical strength properties were affected by the addition of surfactants. Cationic surfactants had the greatest effect on physical properties, decreasing breaking length, and burst while increasing tear. Nonionic surfactants acted in the same way as the cationics except that the per cent changes in physical properties were not as large. Anionic surfactants increased breaking length and decreased burst and tear, the change in burst being slight. The effects of surfactants on the various properties investigated are thought to be the result of surface tension and the relationship of electric charges between the surfactants and the pulp fibers.

Surfactants have been known for many years but it has not been un il recent years that they have become important. Production figures for surfactants in this country show that their manufacture is one of the fastest growing in the chemical industry.

Although surfactants are not primarily manufactured for use in the paper industry, their use has grown to be of considerable importance in that industry. Surfactants are used in the paper industry in the different stages of stock preparation, including pitch dispersion in pulping. Some surfactants are said to aid beating. Other uses in the paper industry include their use for the formulation of coating colors.

Even though surfactants are at present being added to pulp and paper, very little is known about the effect that they have on drainage and physical strength properties. The purpose of this work was to determine what effect surfactants of the different classes have on drainage and physical strength properties of pulp and, if possible, to explain why the changes occur.

There are two main classes of surfactants; they are the nonionic class and the ionic class. The nonionic class has nonionizable, high affinity end groups, usually containing a number of oxygen, nitrogen, or sulfur atoms in nonionizing configuration. The ionic class is divided into two groups, the anionic and the cationic. The anionic group has the elongated low-affinity portion of the molecule, which is the part responsible for surface activity, in the anion while in the cationic group the elongated part makes up the cation (*1*). The elongated portion of the molecule has a low affinity for water and is usually referred to as the hydrophobic group.

There are several subgroups of surfactants and these are given in Table I. Trade names are used in this paper and it may be convenient to refer to Table I for the class, group, and subgroup of a surfactant.

R. V. Touchette, International Paper Co., Ticonderoga Mills, Ticonderoga, N. Y., M.S. Thesis, University of Maine, June, 1958, and L. C. Jenness, Professor of Chem. Eng. and Head of Dept., U. of Me., Orono, Me.

REVIEW OF THE LITERATURE

Although the literature concerning the effect of surface active agents on drainage is limited, there is some important work which should be mentioned.

It has been suspected for many years that certain additives will change the freeness values of a given pulp. In 1935, Lary and Davis (*2*) reported that hydrogen ion concentration was a factor in freeness changes. Some workers now believe that the effects noticed by Lary and Davis depend not on the pH of the stock but in the way in which the pH is adjusted.

Specht (*3*) reported that freeness values were at a maximum at a pH of 5.3 for the pulp he tested. He explained that each pulp has a certain pH at which the freeness value is highest and this pH will be in the acid range. Specht and Connor (*4*) in 1938 in another paper, reported that there is evidence that the use of sulfuric acid to acidify the stock results in a slower drainage rate for the same pH than does alum. They concluded that there is no simple relationship between total acidity and the drainage rate.

Table I. Ionic and Nonionic Surfactants

Cationic group		Anionic group	
Commercial name	*Subgroup active chem.*	*Commercial name*	*Subgroup active chem.*
	Ionic Class		
Onamine RO	Amine	Aliphatic ester sulfate	Sulfate ester sulfate
BTC-824	Quaternary ammonium salt	NSAE Powder	Alkane sulfuric acid
		Xynophos	Complex sodium phosphate

Commercial name	*Type*
Nonionic Class	
Neutronyx 611	Water soluble
G-1690	Water soluble

Adams, Simmonds, and Baird (*5*) found that freeness increased when small amounts of nonalkaline electrolytes are added to pulp suspensions. They summarized that electrokinetic and flocculation phenomena were involved but did not elaborate on this theory.

The literature on the effect of surfactants on physical properties of pulp is also limited, but there are a few references in the literature. Dixson (*6*) reported that a reduction in physical strength properties was noticed when surface active material was present during sheet formation and drying. Dixson believed that surface active agents lowered the hydrophilic character of the pulp fibers.

Erspamer (*7*) reported that sheet formation is affected by surface active agents because they tend to flocculate pulp suspensions according to the relationship between the electrical charge of these agents and that of the fibers. He found that negatively charged surface active agents flocculate positively charged pulp-alum suspension, whereas positively charged agents enhance the positive charge and thus improve the dispersion.

Nicolaysen and Borgin (*8*) reported that the weakening of handsheets noticed when surfactants were added is caused by the decrease in capillary attraction. A second reason for the weakening of a given handsheet was that surface active agents attach themselves to the fibers with their hydrophilic groups and render the surface of the fibers partly hydrophobic.

RESULTS AND DISCUSSION

Effect of Surfactants on Drainage

Drainage characteristics were studied by two methods. In the first method, surfactants were added to pulp and the Canadian Standard freeness was measured. Three surfactants were used in three different concentrations: 1, 2, and 5% based on the dry weight of the pulp. Pulp consistency was kept at approximately 1%. The surfactants used were cationic Onamine RO, nonionic Neutronyx 611, and anionic Xynophos.

Considerable difficulty was experienced in obtaining reproducible freeness values when surfactants were used whereas reproducible results were easily obtained for blanks. This necessitated the taking of many freeness tests for each sample. The average freeness values are shown plotted on Fig. 1.

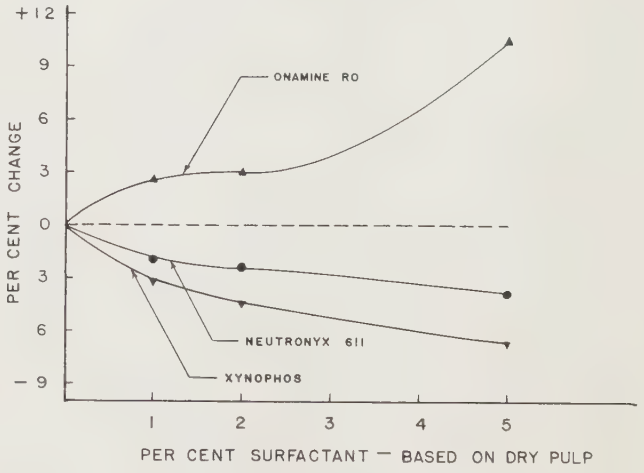

Fig. 1. Per cent change in freeness (C.S.) vs. per cent surfactant

The freeness of the blank was 504 and this was increased to 517 when 1% Onamine RO was added to the pulp. Adding 2% surfactant increased the freeness by only 2 points but when 5% surfactant was used the freeness increased 39 points over the freeness obtained with 2% surfactant. Results for Neutronyx 611 and Xynophos are very similar to Onamine RO in regards to the small change in freeness when increasing the concentration from 1 to 2%. The change noticed when Neutronyx 611 was increased from 1 to 2% is only two points. With Xynophos there is a 6 point change.

These results indicate that only a very small amount of surfactant is necessary to change the freeness of pulp. Since, it is believed, a much lower surface tension results from use of 2% surfactant than if 1% were used, it must be assumed that surface tension is not the only important factor, as the change in freeness owing to use of 2% surfactant is hardly different from use of 1% surfactant. Another important point to notice from Fig. 1 is that freeness increases when Onamine RO is added to

the pulp in all concentrations but the freeness decreases when Neutronyx 611 or Xynophos is used.

Since freeness is a measure of the rate at which water parts from pulp in suspension, and since water must pass through fine capillary passages, the system is subject to the laws of capillary flow. The surfactants used lower the surface tension of the system and it might be expected that the water removal would proceed at a higher rate, thus giving a higher freeness value as measured by a Canadian Standard freeness tester. The rate of water removal was increased for cationic Onamine RO but as previously noted actually decreased with nonionic Neutronyx 611 and anionic Xynophos. It becomes obvious that there must be at least one other factor involved besides surface tension.

It is known that pulp is negatively charged with respect to water. Cationic surfactants contain the low affinity portion of the molecule in the cation which is positively charged. It is conceivable that the low affinity portion, which is the part responsible for surface activity, attaches itself to the cellulose. This

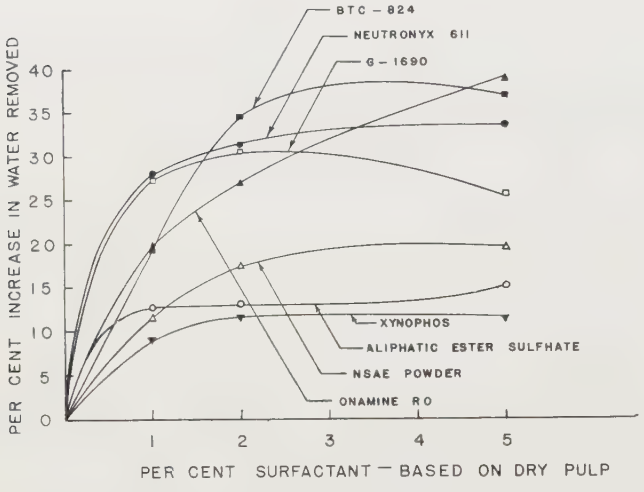

Fig. 2. Per cent increase in water removed compared to blanks vs. per cent surfactant

elongated low affinity portion orients away from the fiber and since it is hydrophobic, causes water to part from the cellulose at a faster rate.

For the anionic surfactants this is not the case. Here the cation of the anionic surfactant would attach to the cellulose and since this portion of the molecule is hydrophilic, it might even be expected to reinforce the hydrophilic character of the cellulose.

The nonionic surfactants are not ionized in solution; therefore, it is doubtful that electric charges have any important effects on drainage or freeness. This is not to say that nonionic surfactants do not attach themselves to the cellulose. It must be assumed in the case of Neutronyx 611 that the molecules attach themselves in such a way on the cellulose that water is not released at as high a rate as would happen if the Neutronyx 611 were not present.

A second method was used to study drainage. It was noticed while making handsheets that when surfactants were used, the formed sheet seemed to contain less water. An empirical test was devised to study this phenomenon. Ten-gram sheets were formed on a Noble and Wood sheet machine and allowed to drain for a constant time of 3 min. The sheet was then removed and weighed. The results of these tests are shown in Fig. 2.

The results are reported as per cent increase in water removed, i.e., the ratio of the additional amount of water removed in the presence of surfactants to that removed in the absence of surfactants. It is interesting to note that in all cases water removal was facilitated by the addition of surfactants. Figure 2 also shows that the nonionic and cationic surfactants best facilitate water removal.

It might at first be thought that the results shown in Fig. 2 conflict with those in Fig 1. That is, Fig. 1 shows that anionic and nonionic surfactants decrease freeness and yet Fig. 2 shows that water removal is facilitated by use of these same surfactants.

The explanation for these results is believed to involve the tests which were used to measure drainage. The Canadian Standard freeness tester measures the *rate* at which water parts from a pulp *suspension*. No attempt is made to measure amount of water removed from a formed sheet in this test, for as soon as the suspension consistency becomes high enough, the water drainage through the wire is no longer collected and therefore not included in the measured value. For the empirically devised test which was run on the Noble and Wood machine in an attempt to measure drainage of water, the most important drainage property measured was the amount of water drained through a *formed* sheet.

In discussing formed sheets as opposed to pulp in suspension, certain definitions must be noted. As used in the above discussion, pulp is said to be in suspension when its consistency is low enough to be fluid. When enough water has been removed so as to form a mat and the consistency is too high to allow the pulp to flow then this is referred to as a formed sheet.

It is believed that two factors are important in drainage of water from pulp when surfactants are used. In all cases there is a surface tension lowering of the water with the use of surfactants and this tends to facilitate water removal, as shown on Fig. 2. The other important factor is the relationship of electric charges between the surfactants and the fibers, such as was discussed under freeness changes.

The freeness test was devised for use by the paper industry in an attempt to show how strongly water is held to pulp after any particular degree of refining. Results are supposed to indicate how the water will leave the pulp from a point at the slice to a point midway down the paper machine wire. The drainage tests done on the Noble and Wood machine are believed to "measure" the way water acts with a given pulp from a point at the slice to a point just past the suction boxes but with emphasis on the point midway down the paper machine wire to a point just past the suction boxes.

To summarize then, the factor of the relationship of electric charges between the surfactants and the pulp fibers seems to be more important in the freeness test with the surface tension lowering factor secondary. After the suspension has formed a mat or sheet, as previously defined, then the surface tension lowering

effect becomes the more important effect while the effect of electric charges becomes secondary.

Effect of Surfactants on Physical Strength Properties

To determine the effect of surfactants on physical strength properties, 1, 2, and 5% surfactant based on the dry weight of the fiber was added to the pulp after beating. Both bleached and unbleached sulfite pulp was used and both were beaten in a TAPPI Standard beater to a Canadian Standard freeness of 500 ml.

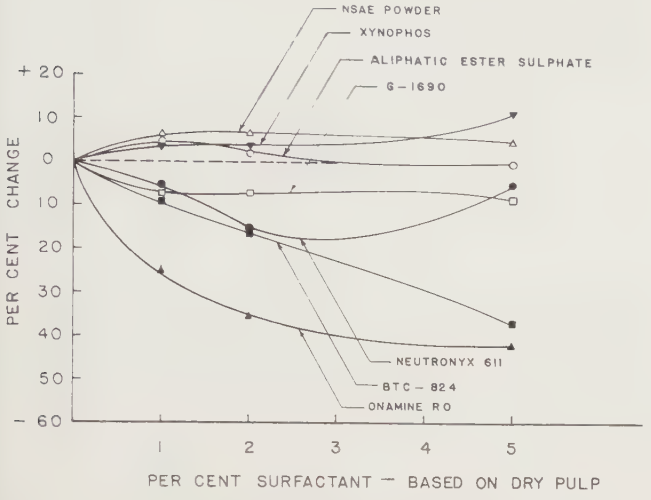

Fig. 3. Per cent change in breaking length vs. per cent surfactant

before the addition of surfactant. The surfactants used were: anionic Xynophos, aliphatic ester sulfate, and NSAE Powder; cationic Onamine RO and BTC-824; and nonionic G-1690 and Neutronyx 611. Handsheets were made in a British sheet machine and evaluated for breaking length, burst, and tear by TAPPI Standard methods.

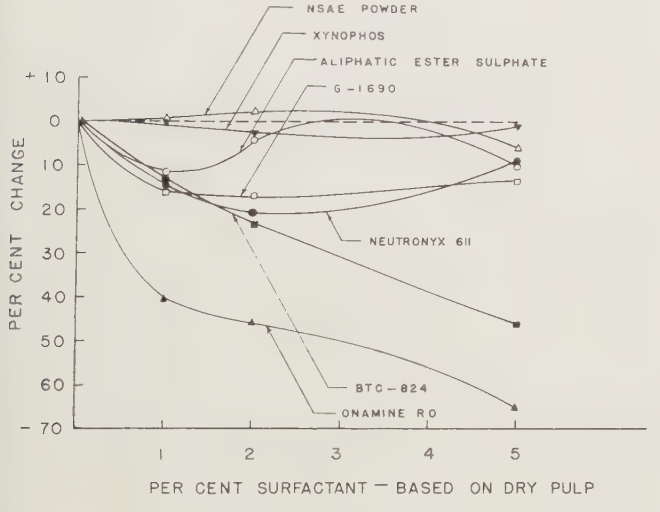

Fig. 4. Per cent change in burst vs. per cent surfactant

The results of physical strength properties of bleached sulfite pulp as affected by surfactants are given in Figs. 3, 4, and 5. Figures 6, 7, and 8 show the effect of surfactants on bleached sulfite pulp as compared to unbleached sulfite pulp.

Figure 3 shows the curves obtained by plotting the percentage change in breaking length for the various surfactants used versus the per cent surfactant used. It can be seen that the two cationic surfactants, Onamine RO and BTC-824, are the most detrimental to breaking length. Per cent decrease in breaking length went from 25.2% when 1% Onamine RO was used to 42.4% when 5% surfactant was used. BTC-824 showed the same general type curve, but values for per cent decrease in strength were not as high.

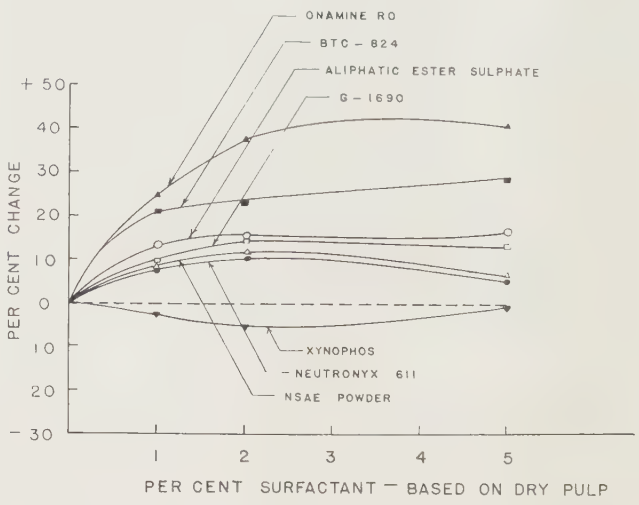

Fig. 5. Per cent change in tear vs. per cent surfactant

These curves are to be compared with the zero line, shown dotted in Fig. 3, when no surfactant was used.

The nonionic agents G-1690 and Neutronyx 611 showed similar curves for breaking length, and per cent decrease in breaking length was not as great for these surfactants as it was for the cationic agents. At 2% concentration, G-1690 had decreased the breaking length by 7.7% while at this same concentration Neutronyx 611 decreased it by 15.3%. At 1 and 5% concentration, values of breaking length for both surfactants are approximately the same.

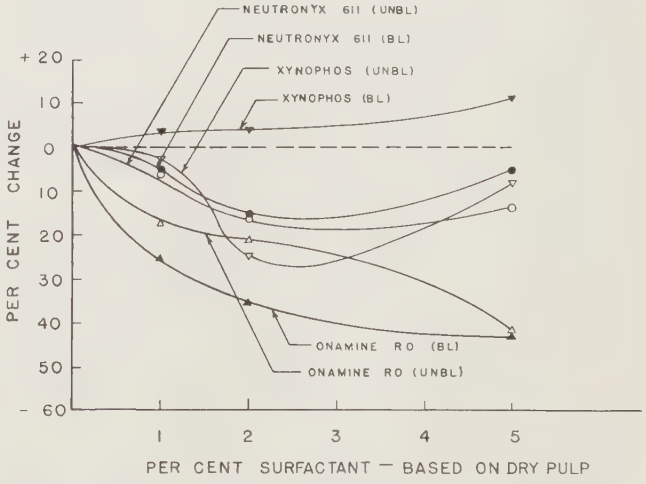

Fig. 6. Per cent change in breaking length; bleached and unbleached sulfite pulp, vs. per cent surfactant

All anionic surfactants increased the breaking length

to some extent. Per cent increase was as high as 7.7% when 1% NSAE Powder was used. Higher concentrations decreased the breaking length but 5% Xynophos produced an increase of 11.7%.

An important point to notice in Fig. 3 is that the cationic surfactants are most detrimental to breaking length while the nonionics are less detrimental, and the anionics actually increase the breaking length. With the exception of the cationics, using more than 1% surfactant seemed to have little effect on breaking length.

Burst values are shown in Fig. 4. It can be seen that the curves for burst factor are approximately the same as the curves for breaking length when

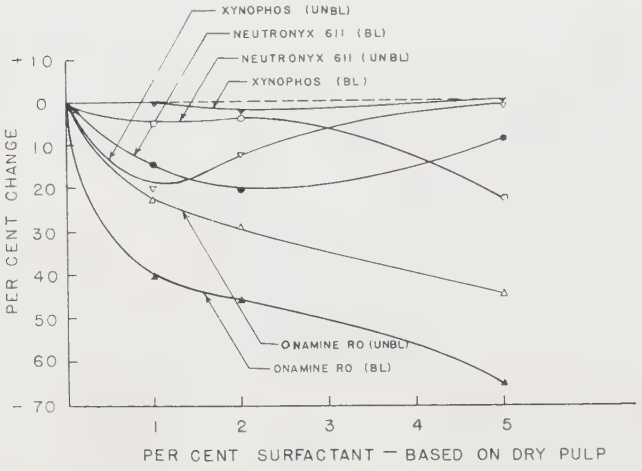

Fig. 7. Per cent change in burst; bleached and unbleached sulfite pulp vs. per cent surfactant

cationic surfactants were used. Onamine RO is again the most influential with a percentage decrease in burst as high as 65.8% at 5% surfactant. Onamine RO is then more detrimental to burst than it is to breaking length. Burst is affected very nearly the same as breaking length, on a percentage basis, when BTC-824 is used.

The nonionics, Neutronyx 611 and G-1690, yield similar curves for burst. With 2% surfactant, burst suffers a maximum percentage decrease of 20.5% for Neutronyx 611 and 17.1% for G-1690.

The anionics influenced burst the least. NSAE Powder is shown to increase burst slightly at 1 and 2% surfactant but to decrease it slightly at 5%. Using Xynophos has a slight detrimental effect on burst. Aliphatic ester sulfate shows an erratic curve. It is not known whether this is due to error in measuring burst or whether the effect is real. At 1% surfactant the per cent decrease is 11.4, at 2%, it is 3.9, and at 5% the decrease is 10.2%.

Figure 4 shows that surfactants seem to be slightly more detrimental to burst than they are to breaking length. The general trend, though, is similar in both cases.

The results of surfactants on tear for bleached sulfite pulp are shown on Fig. 5. It is seen from Fig. 5 that the cationics which were most detrimental to breaking length and burst are most beneficial to tear. The only surfactant which decreased tear was Xynophos. For Xynophos, tear was decreased a maximum of 5.9% when 2% surfactant was used.

Figure 6 shows the effect of surfactants, in different concentrations, on breaking length of unbleached as well as bleached sulfite pulp. Cationic Onamine RO is seen to decrease breaking length of unbleached sulfite less than it did for bleached sulfite. For nonionic Neutronyx 611 the opposite is true. Neutronyx 611 decreased the breaking length of unbleached sulfite more than it did for the bleached sulfite at every concentration. Xynophos increased the breaking length of bleached sulfite, but the curve for unbleached sulfite is probably in error. Not enough points are given to justify the shape of this curve so that no definite con-

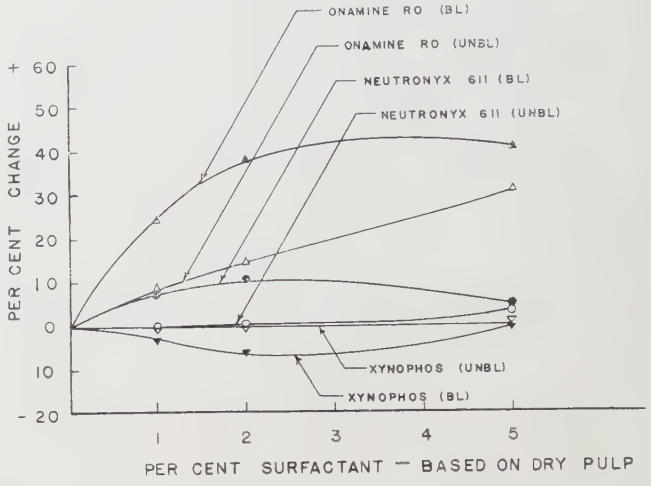

Fig. 8. Per cent change in tear; bleached and unbleached sulfite pulp vs. per cent surfactant

clusions can be drawn. Probably the only thing that can be deduced from this curve is that Xynophos decreased the breaking length of unbleached sulfite pulp more than it did of the bleached sulfite pulp.

The effect of surfactants on burst in bleached and unbleached sulfite is given in Fig. 7. Cationic surfactant Onamine RO decreased burst more in bleached sulfite than it did for the unbleached sulfite. This is opposite to the effect of Neutronyx 611 on breaking length where this surfactant decreased the breaking length of the unbleached sulfite pulp more than it did of the bleached. Anionic Xynophos had very little effect on the bleached sulfite, increasing the value of burst slightly at 2% surfactant but Xynophos lowered the burst of unbleached sulfite considerably.

Values of tear, using different surfactants, on both bleached and unbleached sulfite are shown graphically in Fig. 8. Tear was most affected by Onamine RO for bleached sulfite pulp. Neutronyx 611 also increased tear more for the bleached sulfite pulp than for unbleached sulfite pulp. Xynophos, on the other hand, decreased tear and here again tear decreased most with bleached sulfite pulp.

It is difficult to compare the results of physical strength properties with those found in the literature. Different surfactants were used in the few articles that have been published and no published material was found which contained physical property changes with nonionic surfactants. Dixson (*6*) found that

cationic surfactants decreased physical strength properties more than did anionic surfactants. He explains that the cationic surfactants are more strongly sorbed on cellulose than are the anionic surfactants, and therefore lower the strength properties more. The results discussed in this section seem to verify this theory, and it may be possible now to carry this theory a step further.

It is thought that cationic surfactants are strongly sorbed on cellulose because the elongated low affinity portion of the molecule is contained in the cation and is positively charged. This portion of the molecule attaches itself to the negative cellulose and since it is hydrophobic, tends to decrease the hydrophilic character of the pulp thus resulting in lower physical strength properties. This theory is supported by the fact that bleached pulp, which is more negative than unbleached pulp, is influenced more by cationic surfactants.

CONCLUSIONS

Surfactants were found to affect drainage properties of pulp. Drainage as measured by Canadian Standard freeness was increased when cationic surfactants were added to the pulp but the freeness was decreased when anionic and nonionic surfactants were used. Drainage of water, as measured on the Noble and Wood sheet machine where the water was allowed to drain through a formed sheet or mat of pulp, was facilitated by the addition of surfactants of any class.

Physical strength properties are affected by the addition of surfactants. Both cationic and nonionic surfactants decreased physical strength properties, cationic surfactants having the greater effect. The anionic surfactants increased breaking length slightly but decreased burst slightly.

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RECEIVED Oct. 30, 1959. Presented at the 14th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Pittsburgh, Pa., Oct. 12–15, 1959.

An Experimental Study of the Effect of *Fomes pini* (Thore) Lloyd on the Pulping Qualities of Pond Pine *Pinus serotina* (Michx) Cooked by the Sulfate Process

C. J. REIS and C. E. LIBBY

Mixtures of sound, incipient decay, and advanced decay pond pine infected by *Fomes pini* were pulped by the sulfate process. The pulping experiments indicated that an increase in decay causes a decrease in yield at approximately the same degree of delignification. The resultant pulps were tested for physical properties, and results showed that the breaking length and bursting strength increase and tearing strength decreases with an increase in decay. Folding endurance, apparent density, and brightness are not significantly affected by the fungus. A chemical analysis of the pulps showed that lignin content decreases and alpha-cellulose content increases as the decay advances. A chemical analysis of the wood indicates that the fungus first attacks the lignin which decreases appreciably as the decay advances. Cellulose is not affected until advanced decay sets in. Wood pentosans decrease and extractives in the wood increase with increasing decay.

DURING World War II a heavy demand was imposed on one of the most important natural resources—our woodlands. Wood in its natural form and the products derived from it, such as pulp and paper, were called upon to perform functions which, up to that time, had been assigned normally to metals, plastics, and textiles. Because wood, pulp, and paper performed so satisfactorily in their temporary functions during this period, and usually at a cheaper cost, the American public began to demand greater use of wood and paper in more and more products. This demand has resulted in making the United States the first nation in the world in the per capita consumption of wood, pulp, and paper.

The total pulpwood requirement for pulp, paper, and paperboard, as well as for rayon, lacquers, plastics, etc., has been predicted by the Stanford Research Institute (*1*) to be 38.1 million cords by 1965 and 47.5 million cords by 1975.

It should be emphasized that this prediction is for pulpwood only. Other wood-using industries are looking ahead to similar expansion and greater consumption of wood.

At the present time the 13 Southern states produce over 50% of the nation's pulpwood supply and manufacture 65% of the nation's paper (*2*). If the forecasts of the Stanford Research Institute prove true, the task of providing the basic raw material—pulpwood—will

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fall on our southern forests, which fortunately have the advantages of good soil and climatic conditions favoring rapid timber growth. Another advantage is the year-round logging season which facilitates timber harvesting.

Many years ago some of our paper companies had the foresight to realize that our so-called "inexhaustible" forests would not support the American economy in the years ahead. These companies, together with other paper companies since that time, initiated land procurement programs either by purchasing land or by long-term leases with timber rights. Much of this timber land, especially that acquired in recent years, was located in the coastal plains of the South. Some of these areas, known as "pocosins," were at times inaccessible and no forestry practices could be carried on. Forest fires could not be controlled, wind and hurricane damage could not be repaired, and insect and disease control was impossible.

Cruikshank (*3*), speaking about the southern forests as a source of pulpwood says, "One of the major problems to be solved before we can make substantial progress toward increasing the annual yield of wood is to control timber losses from such destructive agencies as fire, insects, and diseases." Another problem is the use of decayed wood for the manufacture of pulp at a fair profit. These problems, however, do not concern only the South, but the entire United States.

This study was made to determine whether or not decayed wood, in this case pond pine, may be used to meet the demands for additional wood resources for the manufacture of paper pulp.

The problem of whether decayed wood can be used in the manufacture of pulp has been discussed by men in the paper industry for many years. Some pulp manufacturers have been reluctant to use decayed wood because they believe that such wood has a detrimental effect on the resultant product. Other pulp technologists expressed the opinion that use of decayed wood had no effect on the final product.

LITERATURE SURVEY

Pond pine, which has also been called black pine, marsh pine, pocosin pine, and bay pine, is distributed from Cape May, N. J., to as far south as east central Florida. It is a medium sized tree, attaining a height of from 50 to 80 ft., and has a trunk of from 1 to 2 ft. in diam. Pond pine is best suited to low, poor, flat, undrained sandy soils of the type frequently found in pocosins.

Pocosins are elliptical shaped areas of nondraining uplands which are depressed below the general level of the ground, and have well-defined sand rims which rise above the general level of the ground. The hollows are usually filled with water. Wells and Boyce (*4*) have explained the origin of pocosins by their meteorite theory. Other theories have been advanced by Prouty (*5*).

North Carolina has approximately 1.5 million acres of pond pine forest, which accounts for 7% of the state's total forest area. An accurate estimate of the incidence of red heart decay caused by *Fomas pini* is not available for the state. A very good estimate can be made, however, from the data compiled at the Hofmann Forest by the School of Forestry at North Carolina State College. These data indicate that from 90 to 95% of the pond pine growing in this forest is infected with *Fomes pini*.

Fomes pini, because of its large number of hosts and its common occurrence, can be considered one of the most destructive fungi in the forest, and is therefore of great economic importance in the forest products industry.

The susceptibility to *Fomes pini*, formerly known as *Trametes pini* (Thore) Fries, of different species of wood varies. Gussow (*6*) has reported it to occur in 82 species of deciduous and coniferous trees. Boyce (*7*) states that reports of hardwoods being attacked are doubtful, but Percival (*8*) has found it to occur on birch, maple, and hawthorne. Abbott (*9*) states that the most susceptible species of the conifers are tamarack, pine, hemlock, spruce, and balsam, in that order.

This fungus may be found throughout the temperate zone of the northern hemisphere wherever coniferous forests exist. It has been reported from virtually every state of the United States, from Alaska and the Philippine Islands, and from every country north of the Mediterranean Sea, India, Japan, and the West Indies (*8*). Haddow (*10*) mentions that there is no record of the occurrence of *Fomes pini* in the southern hemisphere.

Because of its wide variation in form and its apparent worldwide distribution, *Fomes pini* has been known by many names. The following synonyms are listed by Murrill (*11*):

Bolilus pini Thore
Daedalea pini Fries
Polyporus pini Pers.
Fomes abietis Karst.
Trametes pini Fries.
Polyporus pineinus Peck
Trametes pini abietis Karst.

To this list Percival (*8*) has added:

Ochroporus pini Schrot.
Polystictus pineinus (Peck) Sacc.
Porodaedalea pini (Thore) Murr.
Phellimies pini (Thore) Ames
Xanthochrous pini (Brot.) Pat.
Xanthochrous abietis (Karst.)

On the basis of their chemical action there are two classes of wood-destroying fungi—those causing "white" rots and those causing "brown" rots. The white rots, also called delignifying or corrosion rots (*12*, *13*), are caused by those fungi which dissolve chiefly the lignin of the cell walls and leave the light-colored cellulose behind. Hawley, Fleck, and Richards (*14*) state that white rot fungi are also capable of attacking the cellulose portion of wood but only after much of the lignin has been dissolved.

The brown rots, sometimes referred to as carbonizing or destruction rots (*12*, *13*), are defined as those which preferentially destroy carbohydrates, leaving lignin more or less unchanged. The enzymatic activity of the fungi in the brown rot group is regarded as hydrolytic, whereas fungi in the white rot group may be both hydrolytic and oxidative.

Wood passes through various stages of decay from the sound to that of complete decay. The earliest stage, known as incipient, is hard to detect. The wood

appears to be hard and firm and only a color change is present to reveal the affected areas.

After the incipient stage is passed, the wood becomes noticeably affected until a stage is reached where the wood is completely changed in appearance and structure. This is known as the advanced stage in which the wood can be crumpled between the fingers.

In a decaying tree all three stages are present, passing up and down the tree from the advanced stage, where the decay has been at work the longest, to incipient decay and sound wood. Vertically, incipient decay may extend from a few inches to many feet beyond advanced decay. Horizontally, incipient decay extends from one to two inches beyond advanced decay.

Fomes pini is a white-rot fungus which occurs relatively high in the bole of the tree (*15*). The fungus has been found to be present in the roots as well as the branches of trees (*8, 16*).

Kress (*17*) was one of the earliest workers to make a comprehensive investigation of the problems involved in the utilization of decayed pulpwood. He found that groundwood pulp made from decayed wood (nature of decay was not mentioned) contained shorter fibers, was much darker in color, possessed reduced strength properties, and gave a lower yield than from sound wood. He also found that decayed wood caused machine operation difficulties and increased foaming, size requirements, and dirt content.

These results were confirmed by Bray and Staidl (*18*). Chemical analyses and pulping trials of spruce, balsam, hemlock, and aspen wood in various stages of decay showed that the groundwood pulps contained almost the same amount of cellulose as the pulp obtained from sound woods, although the yields were lower. The pulps from all of the decayed wood were dirty and possessed little strength. They also presented difficulties in the papermaking operation by sticking to couch and press rolls.

Rue, Miller, and Humphrey (*19*) investigated decayed woods cooked by the sulfite process. They found that, with the exception of samples of wood decayed by *Fomes pini*, the pulps obtained were not materially weaker nor the yields much lower than that from sound wood. The color was somewhat darker, however. Wood decayed by *Fomes pini* produced higher pulp yield on a weight basis but lower on a volume basis.

In a study of decayed wood for use in the manufacture of sulfite pulp, Wegelius (*20*) found that the resistance of the pulp to water, acids, and bases decreased with increased decay. Cellulose, lignin, and pentosan content remained relatively constant, but the ash content increased with decay.

Holzer (*21*) studied the effects of decay in western hemlock heartwood. Although the agents of decay were not identified, his results confirmed those of earlier investigators in that the sulfite pulp yields were found to be almost constant on a weight basis, while the color was darker and the strength diminished with increasing decay.

In addition to the study of the effects of decayed wood on groundwood and sulfite pulps, Bray and Staidl (*18*) studied the characteristics of decayed wood cooked by the soda process. It was found that the pulp made from badly decayed spruce wood was very raw, which the authors attributed to the incompleteness of the cook as a result of the neutralization of the alkali. The degradation of wood components into simpler compounds and the increase in acidity with decay was said to explain the consumption of alkali cooking liquor during early stages of the cook. The pulp was high in lignin content and gave high alkali solubility values.

Using decayed poplar and white birch, Sutermeister (*22*) found the yields of soda pulp to be much lower than the yields from sound wood. In addition, he found that the use of decayed wood caused difficulties in bleaching operations, and that extensive fiber disintegration occurred during beating. Since the fungi responsible was not described, Sutermeister's results are difficult to interpret.

Martin (*23*) carried out sulfate cooking experiments on *Fomes pini* infected Douglas-fir, sound mountain hemlock, sound noble fir, and sound lodgepole pine. He found that pulps made from Douglas-fir containing three stages of decay, i.e., incipient, intermediate, and advanced, were equal in yield and had a lower bleach requirement than pulp made from sound wood. His results indicated that the pulp made from decayed Douglas-fir wood is lower in bursting strength, in proportion to the amounts of decay, than the pulps manufactured from sound wood.

An extensive literature survey has shown that no investigation has ever been carried out on both the chemical and physical properties of pulp manufactured from pond pine by the sulfate process after the wood had been infected with *Fomes pini*. Hofmann (*24*) investigated the physical properties of this type of pulp but did not make any chemical analyses to determine the effect of this fungus on the composition of these pulps.

The bole of a tree is characterized by two different types of wood, i.e., juvenile wood and mature wood. Juvenile wood is a term sometimes applied by foresters and wood technologists to wood with relatively wide growth rings that is formed near the pith of the stem.

Juvenile wood is followed by growth with a progressive reduction in ring width. This growth consists of a type of wood commonly called mature wood. The number of years involved in the change from juvenile to mature wood differs from species to species and even from tree to tree of the same species (*25*).

The change from juvenile to mature wood is not abrupt. A zone of transition separates the two types of wood which has neither the characteristics of mature nor juvenile wood.

Some of the properties associated with juvenile wood are lower specific gravity, and shorter fiber length as compared to mature wood (*26, 27*). Other properties of juvenile wood investigated at North Carolina State College, the results of which study have not yet been published, are more compression wood and lower fiber yield per unit weight. Watson, *et al.* (*28*), found that juvenile wood fibers possess inferior strength properties as compared to the fibers of mature wood.

PROCEDURE

The wood for this study was obtained from the wood-collecting yard of the Halifax Paper Co. Maysville, N. C. The wood was harvested on the 78,000-acre Hofmann Forest, which is owned by the North Carolina

Table I. Percentage of Wood Type in Mixture

Mixture	Sound wood	Incipient decay wood	Advanced decay wood
A	100	0	0
B	0	100	0
C	0	0	100
D	75	25	0
E	50	50	0
F	25	75	0
G	75	0	25
H	50	0	50
I	25	0	75

Forestry Foundation and used as an experimental forest by the School of Forestry at North Carolina State College. Pond and loblolly pine, together with various hardwoods, characterize this tract.

The yard superintendent was requested to select the trees at random and to ship approximately one-half cord. This shipment consisted of two bolts of sound wood, four bolts of wood having incipient decay, and four bolts of wood having advanced decay.

In this study, wood infected with incipient decay was designated as that wood which was hard and firm but possessing a definite color change from normal wood. Wood which contained pockets of white material and which could be crumpled between the fingers was designated as being infected with advanced decay.

Samples of the diseased bolts were shipped to Ross W. Davidson, officer-in-charge of the Forest Disease Laboratory at Beltsville, Md., for a positive identification of the fungus. From his examination he stated that *Fomes pini* was undoubtedly causing most of the decay.

Recognizing the fact that the properties of juvenile wood could effect the results of this study, the volume of this particular type of wood was measured. The assumption was made that the core of juvenile wood was a perfect cylinder extending the length of each section. Of the total volume of incipient and advanced decay wood used, only 5% was juvenile wood. Sound wood contained only 2% juvenile wood.

After barking, the *Fomes pini* infected portion of the diseased bolts was separated from the sound outer layer of wood by sawing on a band saw. Before chipping, the bolts consisted of 8-in. diam. cylinders of completely incipient and completely advanced decay wood, and 12-in. diam. cylinders of sound wood.

The bolts were then passed into a two-knife 24-in. chipper manufactured by the Appleton Machine Co. Although the chipper knives were set to produce chips $^{7}/_{8}$ in. in length, the moist condition of the bolts caused the chips to cling together in the form of large "cards." It was necessary to break these cards up by hand before screening the chips.

A chip screen manufactured by The Orville Simpson Co. was used to remove slivers, oversize chips, and sawdust from the chips. The top screen had 1.5-in. mesh openings and the bottom screen had $^{3}/_{16}$-in. openings. Oversized chips were broken up by hand and again screened. Undersize chips were retained for chemical analysis. The sound wood and two stages of decayed wood were chipped and screened separately and kept segregated at all times.

Undersized chips (fines) from the screening operation were mixed by the tabling method and sampled by quartering in a manner prescribed by TAPPI Standard T 605. The fines were then ground in a Wiley mill

Table II. Specific Gravity and Density Values of Sound Pond Pine and That Infected with *Fomes pini*

	Specific gravity	Density, lb./cu. ft.
Sound wood	0.442	
	0.446	
	0.444	
	Av. 0.444	27.71
Incipient decay wood	0.445	
	0.442	
	0.443	
	Av. 0.443	27.54
Advanced decay wood	0.421	
	0.418	
	0.420	
	Av. 0.420	26.21

and screened on a Ro-tap testing sieve shaker according to TAPPI Standard T 11. The acceptable size was stored in fruit jars after attaining average atmospheric conditions prevailing over a period of 4 days. Each stage of diseased wood was processed separately.

After three determinations of moisture content were made on each stage of decay, a complete chemical analysis was performed. The procedures followed were those of Bray (*29*), Phillips (*30*), and TAPPI Standard T 19.

Triplicate determinations of moisture content and specific gravity of the chips were made in accordance with TAPPI Standard T 18. These data were necessary to properly calculate the liquor-to wood ratio, to determine the percentage yield of pulp on the weight of wood, and to determine what effect the disease had on the density of the wood.

Pulping was accomplished in a 1 cu. ft., experimental, stainless steel, stationary digester manufactured by E. C. Wolferz Alloy Equipment Co., Belleville, N. J. This digester was equipped with an inset thermometer well, a steam gage, an exhaust line, a safety valve, and an external circulation system for indirect heating of the cooking liquor.

To determine the effect of the two stages of decay on the pulp, 18 individual cooks consisting of nine different mixtures of sound and decayed wood were carried out. Table I shows the composition of these mixtures.

From information acquired from preliminary cooks, it was decided to cook the wood under the following conditions: liquor-to-wood ratio, including moisture in chips, 3.5 : 1; 25% sulfidity; 17.5% alkali as Na_2O; time to reach maximum temperature of 170° C., $^{3}/_{4}$ hr; time at maximum temperature, $2^{1}/_{4}$ hr.; weight of moisture-free wood, 3000 g.

After adding the wood to the digester, cooking liquor and water were added to satisfy the predetermined cooking conditions. A sample of the liquor was taken before and after cooking to determine the active alkali in grams per liter, expressed as Na_2O. At the end of the digestion period the digester contents were discharged by relieving the digester to atmospheric pressure, flushing with hot water, and forcing the chips out through the bottom opening into a disintegrating tank filled with warm water. The contents of the disintegrating tank were agitated until all of the chips were broken up. The pulp was screened, washed, pressed, weighed, and finally stored in moistureproof bags after the yield had been determined.

The pulps were beaten in a Valley beater for 90 min.

according to TAPPI Standard T 200, and freeness determinations were made every 15 min. according to TAPPI Standard T 227. Handsheets were made from the beaten pulp and tested according to TAPPI Standards T 205 and T 220, respectively.

Table III. Chemical Composition of Sound and Two Stages of *Fomes pini* Infected Pond Pine

	100% Sound wood	*100% Incipient decay wood*	*100% Advanced decay wood*
Ash, %	0.26	0.22	1.21
Extractives, %			
Cold water	2.60	2.74	2.54
Hot water	0.47	4.72	8.21
Alcohol-benzene	2.21	8.49	44.68
Ether	0.64	4.48	13.10
1% NaOH[a]	10.53	19.80	48.40
10% KOH[a]	19.52	21.70	25.59
Acetyl groups, %	3.62	3.82	5.76
Pentosans, %	11.30	9.65	5.52
Lignin, %	42.30	37.94	20.84
Cellulose, %	45.70	45.60	32.94
Holocellulose, %	54.76	56.04	37.37

[a] Not corrected for hot water solubility.

After all the physical tests had been performed on the pulp, chemical analyses were made. The duplicate cooks were combined, mixed, and quartered in accordance with TAPPI Standard T 605. The sample to be used for analysis was divided by means of a rasp until the pulp passed a 40-mesh screen but was retained on a 60-mesh screen. The finely divided pulp was then stored in fruit jars after moisture content had been determined. The chemical analyses performed, all in accordance with TAPPI Standards, were lignin, cellulose, alpha-cellulose, viscosity, and 1% caustic soda solubility.

DISCUSSION OF RESULTS

The results of a series of specific gravity determinations on the sound wood and two stages of diseased pone pine are shown in Table II. The densities, calculated from the average of three determinations of of specific gravity, are also shown.

A reduction in specific gravity begins only when advanced decay sets in. Although it was not brought out in this study, it has been pointed out by Scheffer, *et al.* (*31*), that samples containing incipient decay sometimes show a greater specific gravity than the adjacent sound wood, possibly caused by an accumulation of extractives in the decayed areas.

The results of the chemical analysis of the sound and diseased stages of pond pine are summarized in Table III.

Ideally, an analysis should account for 100% of the wood. This means that there should not be any overlapping or omissions. Such is not the case in this analysis. For example, the total extractives cannot be determined because of possible overlapping of extractives which are soluble in several solvents. Also, there are limitations in the precision of some of the analytical techniques.

The extractives in wood comprise an extraordinary diversity of substances which are removed from plant materials by inert solvents such as ether, alcohol, and water and which do not form an appreciable part of the structural elements or of the wood substances.

Water-soluble materials include inorganic salts, sugars, cyclitols (cyclic polyhydric alcohols), and polysaccharic substances such as gums, mucilages, starch, and galactans. Although hot-water solubility of the flour was carried out for a period of 3 hr., in accordance with TAPPI Standard T 1, it should be mentioned that any method used to determine hot-water solubility will yield additional material upon repeated extractions. This behavior may be attributed to the slow hydrolysis of certain polysaccharide portions of the wood and to the slow dissolving of very slightly soluble materials.

The extractives which are soluble in cold water change little among the three stages of wood used, but the amount of hot water solubles increase considerably as the severity of decay increases.

As can be seen in Table III, the ether and alcohol-benzene solubles of the wood increases considerably as the stage of decay advances. This is particularly true of the alcohol-benzene solubles. Kurth (*32*) has listed the ether extracts of wood as fats, fatty acids, resins, resin acids, waxes, and nonvolatile hydrocarbons. Alcohol-benzene removes the substances soluble in ether and, in addition, dissolves tannins, phlobaphenes (tanninlike substances), and coloring matter.

The ease of solubility of wood in 1% NaOH is an indication of the fungus decay which has taken place in

Table IV. Cooking Conditions and Yields of Sulfate Pulp from Sound and Decayed Woods

Cook no.	*Wood cooked, %*	*Active alkali in g.p.l. Na_2O*	*Final conc. g.p.l. Na_2O*	*Permanganate no.*	*Yield*		
					Screen, %	*Rejects, %*	*Total, %*
1	100% Sound wood	49.57	15.20	20.28	47.33	5.00	52.33
2	100% Sound wood	48.62	17.75	18.77	43.55	4.47	48.02
3	100% Incipient decay	46.81	19.92	21.36	36.68	5.80	42.48
4	100% Incipient decay	47.06	19.34	22.66	36.53	5.80	42.33
5	100% Advanced decay	46.81	17.90	21.82	21.07	6.47	27.54
6	100% Advanced decay	49.26	15.11	22.05	24.06	8.22	32.28
7	75% Sound wood, 25% incipient decay	49.59	16.06	20.45	41.10	4.97	46.07
8	75% Sound wood, 25% incipient decay	53.85	17.07	20.67	40.93	4.97	45.90
9	50% Sound wood, 50% incipient decay	49.01	17.80	21.93	40.13	7.23	47.36
10	50% Sound wood, 50% incipient decay	47.53	13.16	21.84	42.40	6.57	48.97
11	25% Sound wood, 75% incipient decay	41.37	14.87	22.75	37.89	5.87	43.76
12	25% Sound wood, 75% incipient decay	49.74	17.96	21.57	38.23	6.10	44.33
13	75% Sound wood, 25% advanced decay	48.27	14.04	21.01	37.33	3.57	40.90
14	75% Sound wood, 25% advanced decay	47.19	14.75	21.71	36.44	2.93	39.37
15	50% Sound wood, 50% advanced decay	47.91	16.06	21.84	32.63	5.33	37.96
16	50% Sound wood, 50% advanced decay	45.90	19.83	22.43	34.47	4.47	38.94
17	25% Sound wood, 75% advanced decay	47.40	13.01	22.31	30.10	5.67	35.77
18	25% Sound wood, 75% advanced decay	47.05	11.78	22.30	29.65	6.38	36.04

Liquor–to–wood ratio, 3.5:1.
Sulfidity, 25.0%.
Alkali as Na_2O, 17.5%.
Cooking time, 3 hr.

a given wood sample. As the wood decays, the percentage of alkali-soluble material increases. Although the solubility of normal, sound wood in this test is quite appreciable, it increases considerably as the stage of decay advances. The increase is directly proportional to the decrease in pulp yield caused by the decay.

The acetyl groups also increase as the stage of disease advances. There is only a 5% rise from the sound to the incipient stage of decay, but, as is evident from Table III, there is a 59% increase from the sound to the advanced stage of decay.

Acetyl groups are those which yield volatile organic acids upon hydrolysis (*33*). These acids are apparently combined as esters, and are present wholly in the polysaccharide portion of the wood. Acetic acid usually represents the larger portion of the volatile acids with formic acid accounting for the remaining portion.

It is evident from Table III that *Fomes pini* affects pentosan content of the wood, which decreases from 11% in sound wood to 5.5% in the advanced decay wood. Pentosans are a part of the noncellulosic carbohydrates present in wood and consist chiefly of xylan and araban. The determination of pentosans is always based on their conversion through acid hydrolysis into

Table V. Strength and Other Physical Properties of Pulps from Mixtures of Sound and Incipient Decay Pond Pine

		Mixture														
		A 100% Sound 0% incipient decay			D 75% Sound 25% incipient decay			E 50% Sound 50% incipient decay			F 25% Sound 75% incipient decay			B 0% Sound 100% incipient decay		
	Beating time, min.	1	2	Av.	1	2	Av.	1	2	Av.	1	2	Av.	1	2	Av.
Freeness, ml. (Canadian Standard)	0	767	770	769	735	749	742	728	745	737	760	748	754	760	732	746
	15	757	752	750	705	710	708	690	710	700	707	715	711	705	705	705
	30	650	640	645	615	630	622	602	615	609	630	632	631	625	622	624
	45	485	492	489	455	480	468	430	437	434	475	495	485	465	417	441
	60	302	320	311	287	302	295	265	255	260	300	330	315	290	287	289
	75	180	195	189	160	210	185	150	142	146	220	200	210	175	159	167
	90	111	97	104	95	105	100	90	67	79	105	125	115	113	94	104
Brightness, G.E.	0	24.1	23.7	23.9	22.8	23.1	23.0	21.5	19.7	20.6	23.1	23.0	23.0	22.7	21.9	22.3
	15	20.3	20.8	20.6	19.3	19.7	19.5	18.9	16.5	17.7	19.8	19.9	19.9	18.2	18.2	18.2
	30	19.5	18.6	19.0	18.3	18.5	18.4	17.2	14.9	16.1	18.0	17.8	17.9	17.3	17.1	17.2
	45	18.7	18.0	18.4	17.2	17.3	17.3	16.4	14.5	15.5	17.4	16.7	17.1	16.1	16.4	16.3
	60	17.5	17.9	17.7	16.4	16.9	16.7	15.9	13.5	14.7	16.0	15.9	16.0	16.2	15.3	15.7
	75	16.9	17.1	17.0	15.4	16.2	15.8	15.1	12.9	14.0	15.5	15.2	15.3	14.9	14.4	14.7
	90	16.2	15.9	16.1	14.9	15.4	15.1	13.9	12.0	13.0	14.7	14.8	14.8	14.2	14.2	14.2
Stretch, %	0	1.1	1.4	1.3	1.6	1.8	1.7	1.7	1.0	1.4	1.7	1.6	1.7	1.7	2.1	1.9
	15	3.1	2.7	2.9	2.7	3.0	2.8	3.5	3.1	3.3	2.7	2.8	2.7	3.4	3.3	3.4
	30	3.4	3.8	3.6	3.2	2.5	2.9	3.6	3.0	3.3	2.9	3.0	2.9	3.8	3.7	3.8
	45	4.2	3.7	4.0	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.2	3.3	4.0	4.1	4.0
	60	4.2	3.9	4.0	3.6	3.7	3.7	3.8	3.7	3.7	3.5	3.5	3.5	4.3	4.3	4.3
	75	4.3	3.9	4.1	3.8	4.1	4.0	3.9	3.7	3.8	3.5	3.4	3.5	4.3	4.3	4.2
	90	3.8	4.2	4.0	3.8	3.9	3.9	4.0	4.0	4.0	3.8	3.3	3.5	4.4	4.4	4.4
Breaking length, m.	0	1693	2669	2181	2951	3320	3136	2649	2187	2418	2854	2860	2857	2629	3302	2966
	15	5560	5371	5466	6403	6795	6600	7611	6530	7070	6114	6198	6156	6259	6689	6474
	30	7146	8379	7762	7289	8235	7762	8812	7360	8087	8322	7944	8133	8374	8155	8265
	45	8079	8109	8094	8761	8912	8837	8486	8773	8630	8288	8583	8436	8789	8959	8874
	60	9057	8815	8936	9208	9106	9157	9359	9453	9406	9698	9392	9645	9356	9789	9573
	75	9100	9133	9116	9547	9751	9649	9408	9381	9395	9723	9663	9693	9530	9361	9445
	90	9147	9029	9089	9576	9900	9738	10293	9821	10057	9379	9550	9465	9421	9656	9539
Burst ratio, p.s.i./lb. basis wt.	0	0.162	0.150	0.156	0.409	0.362	0.386	0.352	0.232	0.292	0.342	0.302	0.322	0.272	0.393	0.333
	15	0.731	0.690	0.710	0.961	0.954	0.957	0.850	0.905	0.878	0.855	0.821	0.838	0.920	0.914	0.917
	30	1.079	1.003	1.041	1.188	1.136	1.162	1.142	1.140	1.141	1.128	1.094	1.111	1.173	1.211	1.192
	45	1.214	1.192	1.203	1.311	1.261	1.286	1.260	1.267	1.264	1.201	1.224	1.212	1.291	1.295	1.293
	60	1.223	1.290	1.257	1.360	1.330	1.345	1.370	1.326	1.348	1.401	1.317	1.359	1.355	1.411	1.383
	75	1.351	1.365	1.358	1.406	1.371	1.388	1.412	1.373	1.393	1.401	1.386	1.394	1.454	1.351	1.402
	90	1.407	1.401	1.404	1.425	1.406	1.415	1.408	1.357	1.382	1.364	1.452	1.408	1.421	1.299	1.360
Tear ratio, g./lb. basis wt.	0	1.086	1.047	1.067	1.325	1.613	1.469	1.433	1.304	1.368	1.556	1.475	1.515	1.230	1.714	1.472
	15	1.595	1.221	1.408	0.983	1.183	1.083	1.194	1.215	1.205	1.236	1.191	1.214	1.310	1.278	1.294
	30	1.448	1.027	1.238	0.930	0.969	0.950	0.979	0.990	0.985	1.026	0.985	1.005	1.142	1.060	1.102
	45	1.239	0.970	1.104	0.850	0.882	0.866	0.890	0.881	0.885	0.816	0.885	0.851	0.973	0.958	0.966
	60	1.031	0.861	0.946	0.822	0.827	0.824	0.788	0.784	0.786	0.844	0.811	0.827	0.935	0.853	0.894
	75	0.933	0.852	0.893	0.725	0.773	0.749	0.728	0.705	0.717	0.720	0.747	0.733	0.760	0.805	0.783
	90	0.918	0.744	0.831	0.713	0.762	0.738	0.619	0.658	0.639	0.643	0.679	0.661	0.883	0.777	0.805
Fold ratio, double folds/lb. basis wt.	0	0.07	0.10	0.09	0.57	0.87	0.72	0.51	0.49	0.50	0.52	0.49	0.50	0.23	0.92	0.58
	15	10.17	8.17	9.17	27.17	19.13	23.15	22.04	28.05	25.05	28.85	24.36	26.61	17.70	20.37	19.04
	30	23.42	36.73	30.08	23.50	32.18	27.84	30.47	50.81	40.64	38.44	36.48	37.46	26.22	32.07	29.14
	45	34.97	36.13	35.55	42.03	44.20	43.12	30.90	40.89	35.90	38.70	50.65	44.68	39.10	43.95	41.53
	60	51.32	38.76	45.04	53.85	61.88	57.87	69.96	65.00	67.48	49.05	59.95	54.50	50.94	59.09	55.01
	75	72.42	49.00	60.71	67.53	66.80	67.17	79.02	64.50	71.76	62.00	77.57	69.79	55.78	70.91	63.35
	90	68.56	64.12	66.34	94.69	85.01	89.85	80.17	70.47	75.32	65.41	75.17	70.29	64.95	91.22	78.09
Apparent density, g./cc.	0	0.261	0.318	0.290	0.349	0.402	0.376	0.373	0.319	0.347	0.385	0.394	0.390	0.316	0.381	0.349
	15	0.490	0.504	0.497	0.604	0.607	0.605	0.596	0.574	0.585	0.580	0.594	0.587	0.545	0.604	0.525
	30	0.581	0.620	0.600	0.698	0.702	0.700	0.685	0.665	0.675	0.649	0.679	0.664	0.640	0.637	0.639
	45	0.642	0.695	0.669	0.732	0.683	0.708	0.775	0.728	0.752	0.760	0.718	0.739	0.674	0.713	0.694
	60	0.660	0.730	0.695	0.758	0.777	0.768	0.817	0.778	0.798	0.744	0.758	0.751	0.718	0.730	0.724
	75	0.709	0.770	0.740	0.798	0.802	0.800	0.855	0.807	0.831	0.792	0.800	0.795	0.783	0.783	0.771
	90	0.711	0.807	0.759	0.828	0.828	0.828	0.839	0.870	0.855	0.875	0.830	0.853	0.800	0.800	0.792

Basis weight = (25 × 40–500).

simple pentose sugars, chiefly xylose and arabinose.

Lignin and cellulose determinations made on the sound wood and two stages of decayed wood indicate that lignin was attacked first and decreased rapidly in amount as the stage of infection advanced. The cellulose portion of the wood remained about the same until the advanced decay stage. At this point it decreased by 13% from that of the incipient decayed wood.

Table IV summarizes the cooking conditions and yields of the pulping operation. As was expected, the screened yield was highest when sound wood was pulped and decreased as the stage of decay advanced. The small differences in the permanganate number indicate that there was approximately the same degree of delignification occurring under the cooking conditions employed.

Presented in Tables V and VI are the data on the strength and other physical properties of the pulps from sound and decayed pond pine.

An examination of brightness indicates that the greatest difference between the 18 pulps, at any particular beating time, is only 4.6. The amount of chemicals required to bleach, to the same brightness (for example, 80 G.E.), several low-color pulps having a difference in brightness of five points is practically the same.

Table VI. Strength and Other Physical Properties of Pulps from Mixtures of Sound and Advanced Decay Pond Pine

	Beating time, min.	A 100% Sound 0% advanced decay			G 75% Sound 25% advanced decay			M xture H 50% Sound 50% advanced decay			I 25% Sound 75% advanced decay			C 0% Sound 100% advanced decay		
		1	2	av.	1	2	av.	1	2	av.	1	2	av.	1	2	av.
Freeness, ml. (Canadian Standard)	0	767	770	769	750	735	742	730	727	728	738	725	732	747	757	752
	15	757	742	750	728	712	712	690	695	693	665	665	665	705	683	694
	30	650	640	645	630	625	625	595	563	579	515	555	535	595	617	606
	45	485	492	489	498	493	496	433	380	407	358	400	379	445	500	473
	60	302	320	311	330	317	324	280	230	255	208	258	233	300	350	325
	75	180	195	189	193	197	195	177	130	154	140	160	150	200	210	205
	90	111	97	104	112	105	109	107	75	91	65	90	78	117	115	116
Brightness, G.E.	0	24.1	23.7	23.9	23.1	23.1	23.1	21.2	21.0	21.1	20.2	20.4	20.3	21.0	20.9	21.0
	15	20.3	20.8	20.6	19.9	19.8	19.9	18.4	18.6	18.5	17.7	18.1	17.9	17.5	17.7	17.6
	30	19.5	18.6	19.0	17.9	17.9	17.9	16.8	17.0	16.9	16.9	17.5	17.2	16.1	16.4	16.2
	45	18.7	18.0	18.4	16.8	16.9	16.8	15.9	16.2	16.0	15.9	16.2	16.1	15.3	14.8	15.1
	60	17.5	17.9	17.7	15.9	16.1	16.0	15.5	15.3	15.4	15.0	15.4	15.2	14.6	14.5	14.6
	75	16.9	17.1	17.0	15.2	15.5	15.4	15.1	14.7	14.9	14.2	14.8	14.5	13.9	13.9	13.9
	90	16.2	15.9	16.1	14.7	14.7	14.7	14.7	14.0	14.4	13.8	13.8	13.8	13.6	13.3	13.5
Stretch, %	0	1.1	1.4	1.3	1.5	1.7	1.6	2.1	2.0	2.1	2.1	2.2	2.2	2.0	1.5	1.8
	15	3.1	2.7	2.9	2.9	2.9	2.9	2.8	2.9	2.9	3.0	3.1	3.1	3.0	2.6	2.8
	30	3.4	3.8	3.6	3.4	3.5	3.5	3.1	3.0	3.1	3.3	3.1	3.2	3.3	3.2	3.3
	45	4.2	3.7	4.0	3.7	3.9	3.8	3.3	3.0	3.2	3.3	3.2	3.3	3.5	3.5	3.5
	60	4.2	3.9	4.0	3.1	3.7	3.4	3.5	3.2	3.4	3.5	3.4	3.4	3.6	3.6	3.6
	75	4.3	3.9	4.1	3.6	3.9	3.8	3.3	3.5	3.4	3.4	3.4	3.4	3.5	3.8	3.7
	90	3.8	4.2	4.0	3.9	3.9	3.9	3.7	3.5	3.6	3.5	3.7	3.6	3.8	4.0	3.9
Breaking length, m.	0	1693	2669	2181	2888	3341	3115	4310	4337	4323	4712	5218	4965	4468	3295	3882
	15	5560	5371	5466	6007	6296	6152	7048	7640	7344	8118	8068	8093	7847	6848	7348
	30	7146	8379	7762	7513	7430	7471	8723	8816	8770	9666	9326	9496	9536	8691	9113
	45	8079	8109	8094	8477	8333	8405	9420	9033	9226	10018	9966	9992	10303	9285	9794
	60	9057	8815	8936	8364	8613	8488	9807	9782	9795	10183	10357	10270	10299	9735	10017
	75	9100	9133	9116	9184	9354	9284	9633	10103	9868	10293	10557	10429	10649	10061	10355
	90	9148	9029	9089	9933	10032	9983	10314	10016	10165	10532	10524	10528	11004	10845	10924
Burst ratio,	0	0.162	0.150	0.156	0.351	0.351	0.351	0.491	0.589	0.540	0.637	0.601	0.619	0.601	0.389	0.495
	15	0.731	0.690	0.710	0.884	0.906	0.895	1.024	0.983	1.004	1.111	1.101	1.106	1.063	01.38	1.052
	30	1.079	1 003	1.041	1.108	1.092	1.100	1.123	1.102	1.114	1.307	1.275	1.291	1.240	1.318	1.279
	45	1.214	1.192	1.203	1.271	1.211	1.241	1.254	1.330	1.292	1.414	1.388	1.401	1.398	1.383	1.391
	60	1.223	1.290	1.257	1.359	1.361	1.360	1.425	1.397	1.410	1.433	1.450	1.441	1.402	1.422	1.412
	75	1.351	1.365	1.358	1.412	1.441	1.427	1.453	1.462	1.458	1.446	1.413	1.430	1.481	1.426	1.454
	90	1.407	1.401	1.404	1.473	1.478	1.470	1.387	1.419	1.402	1.487	1.530	1.509	1.503	1.493	1.498
Tear ratio, g./lb. basis wt.	0	1.086	1.047	1.067	1 392	1.444	1.418	1.388	1.370	1.379	1.318	1.336	1.327	2.058	1.683	1.870
	15	1.595	1.221	1.408	1.083	1.129	1.106	0.996	0.925	0.951	0.903	0.987	0.945	1.058	1.229	1.144
	30	1.448	1.027	1.238	0.886	0.951	0.919	0.833	0.795	0.814	0.804	0.807	0.806	0.869	0.909	0.889
	45	1.239	0.970	1.104	0.784	0.834	0.804	0.781	0.733	0.757	0.739	0.732	0.735	0.756	0.855	0.806
	60	1.031	0.861	0.946	0.765	0.757	0.761	0.712	0.659	0.686	0.678	0.691	0.684	0.735	0.790	0.762
	75	0.933	0.852	0.893	0.697	0.694	0.696	0.684	0.591	0.638	0.612	0.624	0.618	0.695	0.753	0.724
	90	0.918	0.744	0.831	0.685	0.650	0.666	0.612	0.580	0.596	0.585	0.602	0.594	0.693	0.678	0.686
Fold ratio, double folds/lb. basis wt.	0	0.07	0.10	0.09	0.56	0.67	0.62	2.91	6.57	4.74	5.12	8.2€	6.69	2.38	0.72	1.55
	15	10.17	8.17	9.17	17.71	18.50	18.10	22.64	23.98	23.31	20.14	18.73	19.44	19.77	19.84	19.81
	30	23.42	36.73	30.08	29.84	27.87	28.86	38.17	33.98	36.08	40.15	34.67	37.41	29.69	41.38	35.54
	45	34.97	36.13	35.55	47.93	46.07	47.00	42.94	49.03	45.99	38.83	43.42	41.12	43.76	49.45	46.61
	60	51.32	38.76	45.04	47.56	51.55	49.56	53.26	68.37	60.81	55.26	46.11	50.68	48.96	48.33	48.65
	75	71.42	49.00	60.71	57.01	58.14	57.57	54.53	79.14	66.83	69.37	64.55	66.96	49.75	64.41	57.08
	90	68.56	64.12	66.34	72.17	74.41	73.29	78.46	98.75	88.61	98.52	79.07	88.80	66.29	76.12	71.21
Apparent density, g./cc.	0	0.261	0.318	0.290	0.355	0.349	0.351	0.442	0.461	0.452	0.486	0.483	0.485	0.370	0.394	0.382
	15	0.490	0.504	0.497	0.582	0.566	0.574	0.620	0.632	0.626	0.653	0.649	0.651	0.620	0.602	0.611
	30	0.581	0.620	0.600	0.681	0.684	0.682	0.690	0.712	0.701	0.741	0.737	0.739	0.683	0.681	0.682
	45	0.642	0.695	0.669	0.723	0.763	0.743	0.770	0.758	0.764	0.777	0.766	0.772	0.737	0.702	0.720
	60	0.660	0.730	0.695	0.764	0.772	0.768	0.809	0.792	0.800	0.822	0.802	0.812	0.765	0.740	0.752
	75	0.709	0.770	0.740	0.789	0.790	0.790	0.826	0.837	0.832	0.835	0.834	0.835	0.795	0.774	0.785
	90	0.711	0.807	0.759	0.819	0.821	0.820	0.850	0.885	0.866	0.870	0.856	0.863	0.822	0.790	0.806

Basis weight = (25 × 40—500).

Breaking length and burst ratio increased at all beating times as the decay advanced. In the case of pulp from mixture E, these particular properties of both cooks were somewhat out of line when compared to the pulp from mixtures D and F. Figures 1 and 3 show the relationship of the average burst ratio and breaking

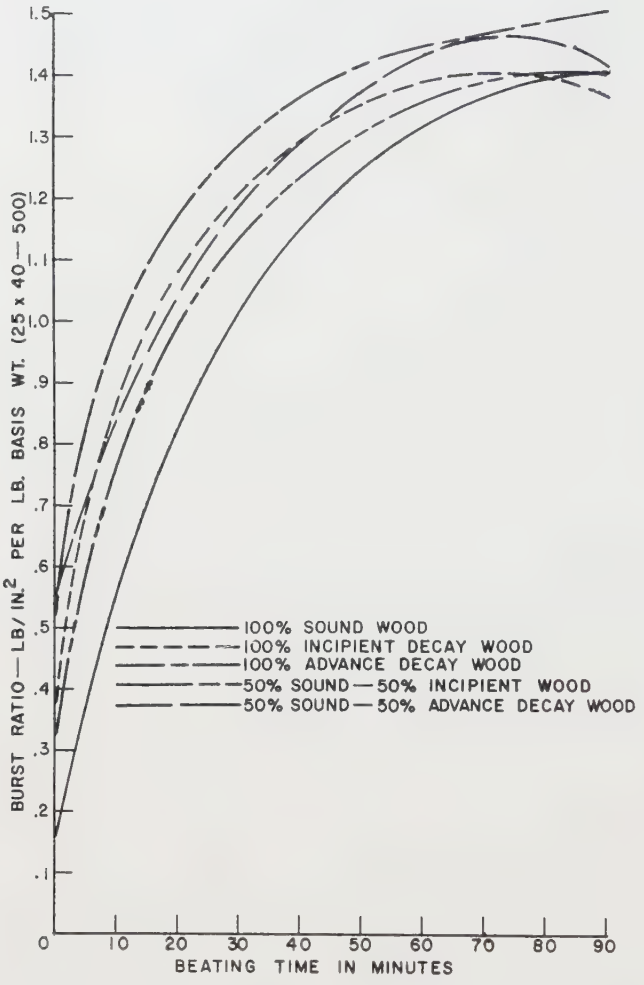
BURST RATIO — LB/IN.² PER LB. BASIS WT. (25 x 40 — 500)
BEATING TIME IN MINUTES
100% SOUND WOOD
100% INCIPIENT DECAY WOOD
100% ADVANCE DECAY WOOD
50% SOUND — 50% INCIPIENT WOOD
50% SOUND — 50% ADVANCE DECAY WOOD

Fig. 1. Curves of beating time vs. burst ratio for pulps from diseased wood

length, respectively, against beating time for five different pulp mixtures.

The tear ratio of the pulps decreases as the severity of the decay increases. The only deviation from this trend is for the pulp from mixtures A, B, and C at zero beating time. Figure 2 shows the average tear ratio plotted against beating time for five pulp mixtures.

It is important to know why tear decreases with beating while other physical properties increase. Fiber length is an important property in papermaking because after maximum fiber-to-fiber bonding has taken place, the strength of the sheet depends principally upon the length of the component fibers. The greater the fiber length, the greater the opportunity for fibrillation. This means that fibers which possess a greater length generally have a higher capacity for interfiber bonding. This is the reason why the longer the fiber length, the less chance there is for slippage between fibers when the sheet is subjected to stress.

The work involved in tearing consists of two components: (1) that involved in pulling fibers out of the paper, and (2) that involved in rupturing the fibers. The tearing resistance of unbeaten pulp is almost entirely due to work involved in overcoming the frictional resistance of the fibers being pulled from the pulp. There is practically no tearing of the fibers, and since

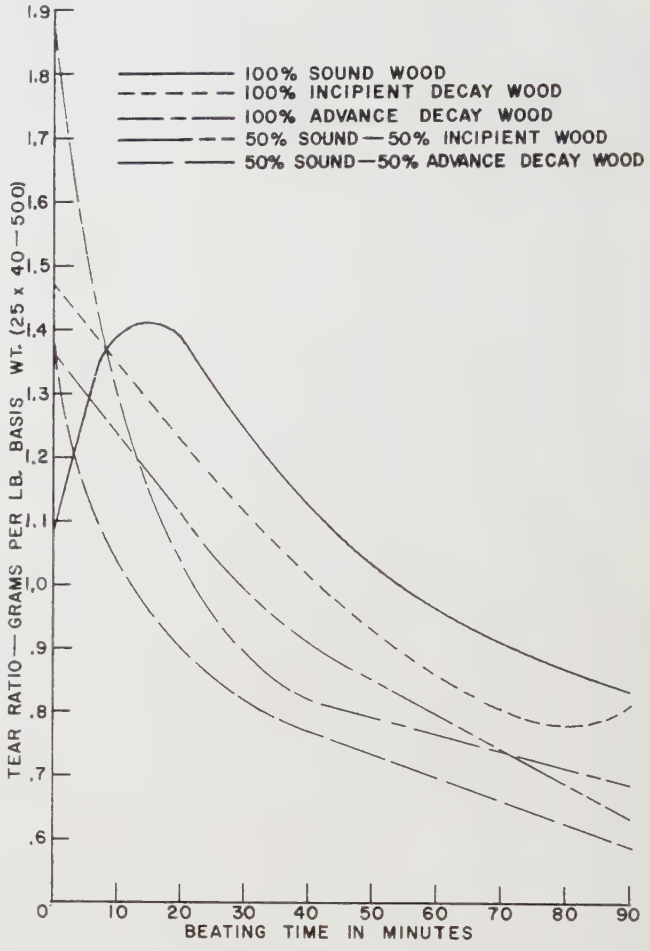
TEAR RATIO — GRAMS PER LB. BASIS WT. (25 x 40 — 500)
BEATING TIME IN MINUTES
100% SOUND WOOD
100% INCIPIENT DECAY WOOD
100% ADVANCE DECAY WOOD
50% SOUND — 50% INCIPIENT WOOD
50% SOUND — 50% ADVANCE DECAY WOOD

Fig. 2. Curves of beating time vs. tear ratio for pulps from diseased wood

the total area of fiber contact is small, due to relatively little interfiber bonding, the frictional resistance is small and the tearing resistance is low. After a slight amount of beating, the interfiber bonding is increased, resulting in greater tearing resistance because of the increased frictional resistance in pulling fibers out of the pulp. This increase in tearing resistance in the early stages of beating is typical of most pulps. As beating is greatly increased, the fibers no longer slip past one another readily because of the increased interfiber bonding, and consequently there is an increase in the number of fibers which are ruptured in tension. This rupture is more nearly a shearing action than a pulling action, and since the work involved in rupturing a fiber is much less than the energy involved in pulling a fiber out of a sheet, the energy required to tear the sheet decreases. In other words, cohesion increases in the sheet which tends to concentrate the tearing force into a smaller area, with the result that lower tearing values are obtained. This is the reason why tearing resistance decreases with beating after an initial increase.

The reason why other physical properties, such as

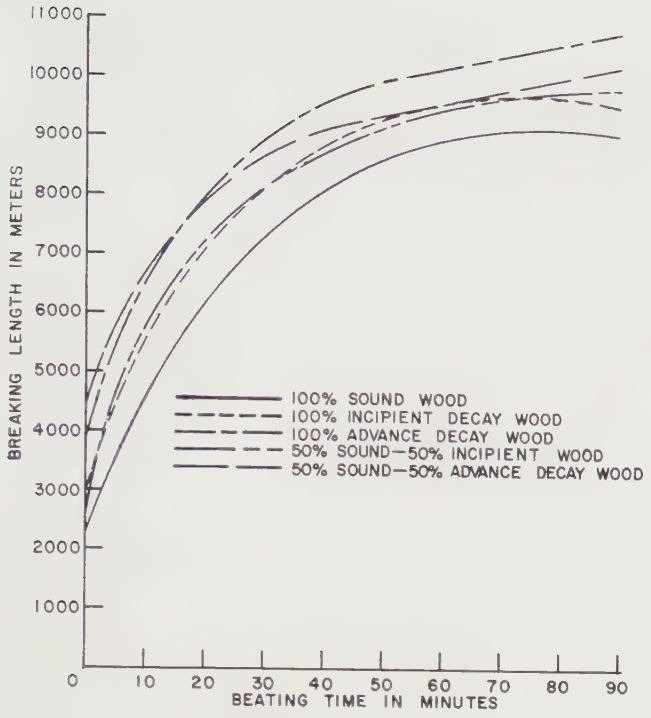

Fig. 3. Curves of beating time vs. breaking length relationship of pulps from diseased wood

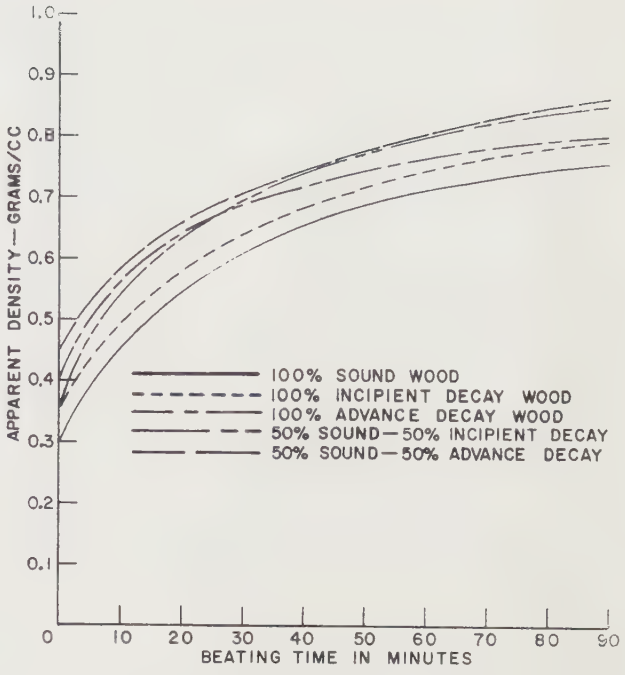

Fig. 5. Curves of beating time vs. apparent density for pulps from diseased wood

burst and tensile strength, increase with beating is that all the work involved is the pulling of the fibers out of the sheet. As beating increases, more fiber bonding takes place, and as was stated above, more work is involved in pulling a fiber out of the sheet than in rupturing a fiber.

In general, it might be stated that tearing resistance is basically dependent upon fiber length. Folding, bursting, and tensile strength are more dependent upon fiber bonding than upon fiber length (*34*).

Figure 4 shows the beating time-fold ratio relationship based on the average of duplicate pulps. A statistical analysis of variance, shown in Table VIII, indicates that wood infected with *Fomes pini* does not have a significant effect on the folding endurance of the pulp.

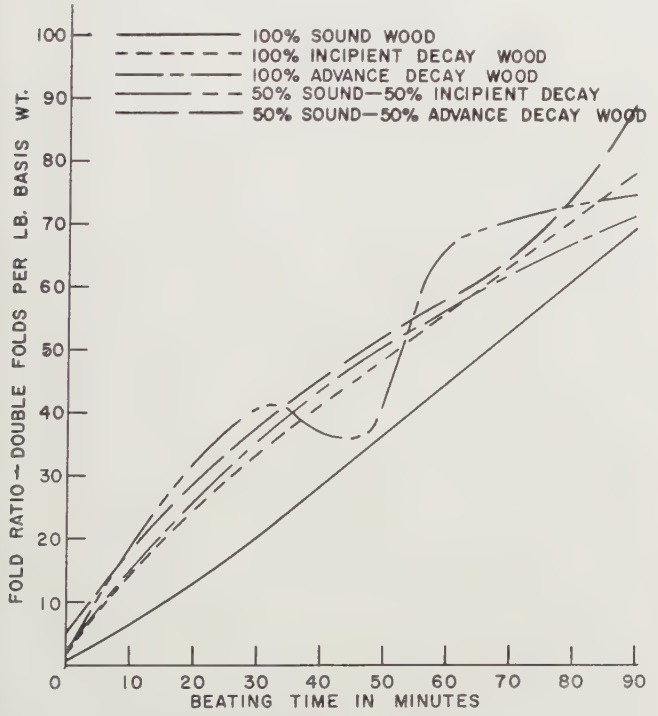

Fig. 4. Curves of beating time vs. fold ratio for pulps from diseased wood

The curve for mixture E shows a deviation from the curves of other mixtures in that there is a sharp decline in fold at 45 min. beating time. This cannot be explained in view of the fact that if the pulp from similar cooks were tested for folding endurance, this deviation would not be expected to occur again.

Figure 5 shows how the pulps from five pulping operations change in apparent density with beating time. Analyzed statistically, *Fomes pini* infected wood does not have an effect on the apparent density of the resultant pulp whereas beating time is highly significant.

The chemical composition of the pulps from the nine different cooks of mixtures of decayed wood is shown in Table VII.

A valuable control test to detect an excessively drastic cooking or bleaching operation is the 1% NaOH solubility of pulp. In general, the less the chemical degradation of the pulp from either cooking or bleaching, the lower is its alkali solubility. The bulk of the material removed consists of pentosans and other carbohydrates which are less resistant to chemical action than cellulose, and of cellulose which has been partially broken down during the process of preparation.

An analysis of the data from the 1% alkali solubility tests on the pulps from the two cooks of mixture A shows an average of 2.09%. This indicates that these cooks were a little more drastic in comparison with the cooks of mixtures B and C, as is evidenced by the average alkali values of the cooking liquor in Table IV. The cooks of mixtures B were the least drastic in terms of alkali solubility of the resultant pulp.

A comparison of the pulp from mixtures A, B, and C indicates that the lignin content is greatest in the pulp from mixture A. When comparing the lignin content of the pulps with the physical strength curves of Figs. 1 to 5, it is evident that the pulps having the higher lignin

Table VII. Chemical Composition of the Sulfate Pulps from Sound and Decayed Pond Pine

Mixture	Pulp	Lignin, %	Cellulose, %	Alpha-cellulose,[a] %	1% NaOH solubles, %	Av. viscosity, cp.	Av. D.P.	Av. M.W.
A	100% Sound wood	5.41	95.43	84.93	2.09	21.45	1890	306,180
B	100% Incipient decay	5.32	95.53	83.73	1.45	21.37	1887	305,694
C	100% Advanced decay	5.01	94.47	85.55	1.64	15.96	1692	274,174
D	75% Sound wood 25% Incipient decay	4.83	95.79	83.63	1.69	16.35	1704	276,048
E	50% Sound wood 50% Incipient decay	4.32	95.23	84.07	1.77	20.88	1872	303,264
F	25% Sound wood 75% Incipient decay	4.61	94.74	81.71	3.04	24.11	1973	319,626
G	75% Sound wood 25% Advanced decay	4.14	93.74	82.37	1.67	22.12	1914	310,068
H	50% Sound wood 50% Advanced decay	4.27	94.55	81.57	1.56	26.28	2027	328,374
I	25% Sound wood 75% Advanced decay	4.19	93.05	83.26	2.71	21.74	1902	308,124

[a] Corrected for ash and lignin.

content produce sheets of lower density and inferior strength, undoubtedly due to poor interfiber bonding. This is not so evident in the cooks of mixed decayed wood.

The cellulose content of the pulps as determined in this investigation is usually referred to as Cross and Bevan cellulose. An analysis of cellulose in the pulp from mixtures A, B, and C indicates that a change does not occur until mixture C is pulped. This appears logical when the nature of the attack of *Fomes pini* is considered, as described by Hawley, Fleck, and Richards (*14*). They conclude, as a result of their studies, that a white rot fungus is capable of attacking the cellulose portions of wood after much of the lignin has been destroyed.

The alpha-cellulose content of the pulps, as shown in Table VII, is higher for the pulp from advanced decay wood (mixture C) than from incipient decay wood (mixture B). Alpha-cellulose content in pulp from advanced decay wood is higher because the fungus attack has been going on for a longer time, removing lignin, hemicelluloses, and beta- and gamma-cellulose, resulting in a pulp of higher purity which cannot be dissolved in 17.5% NaOH.

Alpha-cellulose content is lowest in the pulp from incipient decay wood, because cellulose has not been affected at this stage and more beta- and gamma-cellulose is present to be dissolved by 17.5% NaOH. This results in a lower alpha-cellulose content when calculated on the weight of the entire pulp sample.

The viscosity values of these pulps, employing the cupriethylenediamine disperse method of determination described in TAPPI Standard T 230 sm-50, indicate that the degree of polymerization of the cellulose from advanced decay wood (mixture C) is lower than for pulps from sound wood (mixture A) or incipient decay wood (mixture B). This can be explained by the fact that the cellulose in the pulp from mixture C had been subjected to attack by the fungus for a longer time than that from mixtures A and B. This resulted in a shortening of the chain length of the cellulose molecule.

Table VIII. Analysis of Variance for Strength Properties of Pulps from Mixtures of Sound and Decayed Pond Pine

		Mean squares				
	d.f.	Burst	Tear	Fold	Breaking length	Apparent density
Mixture	8	0.0728[a]	0.1034[b]	177	5.33×10^{6}[a]	0.0019
Time	6	2.5363[a]	1.2583[a]	12336[a]	99.98×10^{6}[a]	0.4290[a]
Mixture by time	48	0.0007	0.0226[a]	4	1.87×10^{5}	0.0036[a]
Duplicates	9	0.0014	0.0239	139	3.99×10^{5}	0.0020
Error	54	0.0042	0.0064	70	2.71×10^{5}	0.0001

[a] Significant at 1% level.
[b] Significant at 5% level.

CONCLUSIONS

1. The yield of pulp from advanced wood is lower than that from sound wood. The more advanced the stage of decay in the wood, the lower the yield.
2. Tearing strength decreases and breaking length and bursting strength of the pulp increase as the stage of decay in the wood advances. Folding endurance and apparent density of the resultant pulp are not significantly affected by the action of the fungus on the wood.
3. The brightness of the pulp is not lowered to any appreciable extent by the action of the fungus on the wood.
4. The lignin content of the pulp decreases as the decay of the wood advances.
5. Cellulose content decreases only slightly in the pulp produced from the advanced decay wood.
6. The alpha-cellulose content of the pulp produced from advanced decay wood is more than that of the pulp produced from sound and incipient decay wood.
7. The degree of polymerization of the cellulose pulp remains almost constant until the advanced decay sets in. At this point there is a considerable decrease.
8. As the stage of decay advances the fiber-to-fiber bonding increases with the result that a stronger sheet of paper can be formed.
9. There was approximately the same degree of delignification of all pulp mixtures under the cooking conditions employed in this study.
10. The cellulose content of the wood remains approximately constant until the advanced stage of decay sets in, at which time it decreases considerably.
11. The lignin content of the wood decreases rapidly as the stage of decay advances.

12. The extractives in the wood removed by various solvents increases as the stage of decay advances.

13. Acetyl groups in the wood increase as the stage of decay advances.

14. Pentosan content of the wood decreases as the stage of decay advances.

15. A decrease in specific gravity of the wood does not occur until advanced decay sets in.

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Received Nov. 9, 1959. Presented at the Alkaline Pulping Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Nov. 4–6, 1959.

Kraft Liquor Sulfidity Control with Sulfuric Acid

Cross Recovery of Hardwood Cold Soda Spent Liquors

J. N. SWARTZ, R. C. MacDONALD, and P. C. HAMBAUGH

This paper describes the system at Bowaters Southern Paper Corp. whereby sulfuric acid is used as make-up sulfur to permit recovery of spent cold caustic pulping liquors, to increase the sulfidity of kraft cooking liquors, and to maintain liquor sulfidity at a desired level. Sulfuric acid (66° Bé.) is mixed with concentrated black liquor from the cascades in an auxiliary mixing tank. The acid reacts with the free caustic and carbonate from the combined kraft and cold soda liquors. Normal salt cake make-up is thereby reduced by an equivalent amount.

It is a well-established fact that wood chips digested in hot alkaline liquor will produce pulp with increasing strength, yield, and at decreasing cooking time as the percentage of sodium sulfide is increased from 0 to the range of 20 to 25%. The benefits of sulfidities [Sulfidity, % = $Na_2S/(NaOH + Na_2S)$ all as Na_2O] above this range are generally of minor significance with one investigating group concluding that sulfidities in excess of 20% have no benefit providing that effective alkali remains constant. However, a comparison of soda pulp (zero sulfidity) with normal kraft pulp (20 to 30% sulfidity) leaves no doubt in the benefits to be derived.

The level of sulfidity in kraft cooking liquors has in the past usually been controlled by operating conditions. That is, the sulfide content of the cooking liquor, rather than being a cooking variable with direct positive control, has been accepted at levels dictated by factors such as pulp production rates and liquor manufacturing rates. A good deal of work has been done on methods of making better use of the sulfur content of salt cake such as black liquor oxidation, the use of elemental sulfur, et cetera, but it seems that this work was motivated more by a threatened salt cake shortage than by a desire to actually control sulfidity at a given level.

In addition to quality control and sulfur efficiency, the need at Bowaters Southern was for a simple system to provide the necessary sulfur to permit burning of spent liquor from a cold caustic operation in the existing recovery furnace. Stream pollution was the major concern; the economics are also important.

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FACTORS AFFECTING SULFIDITY CONTROL

A number of factors have directed increasing attention toward methods of bringing sulfidity as a variable under day to day control. Quality requirements have predicated rigid control of sulfidity. Diversified pulping procedures (particularly attractive for high yield hardwoods) have affected sulfate mill liquor systems when cross recovery methods are introduced. The economics of the sodium-sulfur balance in make-up chemicals has always been a major concern.

The need for controlled product quality has been only too well emphasized by the tight market of the past few years. Pulp buyers have been increasingly insistent on their suppliers maintaining quality standards set in the high range. Top price is paid for top quality only. Adjustment claims for off-quality pulps can be disastrous. Similarly, where the pulp is converted by the manufacturer, uniformity of the finished product, be it newsprint, coated paper or board, is of prime importance. Papermakers have a host of difficult machine variables to contend with, assuming the furnish is uniform. Variations in even one of the fiber furnishes compounds their operating difficulties. Indeed, the elimination of these machine variables will not be completely solved until such time as furnish variables are removed.

Sulfidity is one of these variables. There is considerable controversy as to the degree with which sulfide variations affect pulp quality, but there is no doubt as to the fact that the introduction of sulfur into the lignin molecule aids the dissolution of lignin in alkaline pulps. There is therefore a minimum sulfide level necessary for sustained quality and certainly a maximum level consistent with economic operation.

The problem of maintaining kraft liquor sulfidity is further aggravated in mills which have a more diversified pulping program. A number of kraft mills are also producing various tonnages of other type pulps, particularly from hardwoods, by processes involving the use of sodium compounds other than normal kraft liquors. These processes require recovery of the spent liquors either to maintain production on a competitive economical basis or to prevent stream pollution.

Neutral sulfite semichemical (NSSC) spent liquors may be conveniently recovered by the cross recovery method with kraft liquors. Here the spent hardwood liquors are mixed with the kraft liquors and processed by normal kraft recovery equipment. As the sulfur: sodium ratio of NSSC liquors is higher than kraft liquors the resulting cooking liquor actually has improved sulfidity over straight kraft liquor. The quantity of recoverable spent NSSC liquor depends on kraft mill liquor losses and operating problems; hence hardwood tonnages are limited unless other methods of recovery are employed. Several methods are available in this type operation and are similar to kraft recovery in that multiple effect evaporation followed by incineration is used.

The sulfide-containing smelt liquor, causticized as such in the kraft process, must be converted to sulfite liquor for the NSSC system. This is accomplished in the Mead (*1*) process by treating the green liquor with flue gases.

NSSC pulp production does not therefore require any sulfidity control whether the spent liquor is recovered by cross recovery methods with regular kraft liquors or with separate recovery systems. However, as previously stated, tonnages are limited in the first method and recovery equipment for the latter has only recently been commercially developed. Economics are still being studied.

New pulping processes for hardwood utilization are also being developed which show better promise of competing with softwood pulps. The cold soda process is probably the most recent of these processes which is being put to commercial use (*7, 8*). Sodium hydroxide is the pulping agent and as such is admirably suited to recovery along with kraft liquors provided a sulfidity control is available.

The following calculations indicate the recovery ratios possible with NSSC and cold soda cross recovery systems, assuming 150 lb. per ton salt cake make-up in kraft mill.

NSSC

$$\begin{aligned} 17\%\ Na_2CO_3 \text{ on wood} &= 8.4\%\ Na_2O \\ 6\%\ NaHCO_3 \text{ on wood} &= 2.2\%\ Na_2O \\ \text{Total} &= 10.6\%\ Na_2O \end{aligned}$$

$$@\ 65\%\ \text{yield} = \frac{10.6}{0.65} = 16.3\%\ Na_2O \text{ on pulp}$$

$$@\ 80\%\ \text{recovery} = \frac{16.3 \times 2000 \times 0.8}{100} = 261\ \text{lb./ton pulp}$$

Cold Soda

210 lb. NaOH/ton pulp = 163 lb. Na_2O
@ 80% recovery = 163 × 0.8 = 130 lb./ton pulp

Kraft mill make-up @150 lb salt cake per ton kraft pulp (65 lb. Na_2O) will permit cold soda production at 65/130 or 50% of kraft tonnage and NSSC at 65/261 or 25% of kraft tonnage.

A simple method for sulfur make-up is however a requisite and in this respect differs in degree only from an efficient kraft recovery operation alone.

Chemical losses occur at many points and in a variety of compositions. Further, each mill has its own problems peculiar to the equipment on hand and method of operation. Essentially we are concerned with the two chemicals sodium and sulfur. They are lost at different points in the system and at differing rates, but both their make-ups come from the one source—salt cake.

Sodium losses may be itemized in terms of salt cake as follows:

Stack loss, 30–45 lb./ton pulp
Washer loss, 30–45 lb./ton pulp
Crude soap loss, 25–35 lb./ton pulp
Miscellaneous, 15–25 lb./ton pulp

In terms of recovery efficiency these losses break down as follows:

Na_2O to digester (total), 825 lb./ton pulp
Na_2O make-up (150 lb. salt cake), 66 lb./ton pulp
Sulfur to digester (22% sulfidity), 80 lb./ton pulp
Sulfur make-up (150 lb. salt cake), 34 lb./ton pulp

Under these conditions the soda recovery efficiency is 92%, whereas sulfur efficiency is only 58%. The extra sulfur losses are due to poor conversion efficiency in the furnace, displacement of sulfide as H_2S by carbon dioxide during burning and direct contact evaporation, and multiple effect evaporator losses as mercaptans and sulfides. All of these losses are a function of the sulfidity level in the system which means that more is involved in increasing the sulfidity level than just adding the stochiometric quantity of sulfide computed at any given time. Further, methods of operation and

production rates complicate the sulfur loss picture. Mills with the more efficient sodium recovery systems—minimum leakage, good washing efficiency and minimum stack dust loss—are finding that improvements in their system with respect to soda loss are penalized by low sulfidity cooking liquors. Here the need has been to increase sulfidity not necessarily as a means of

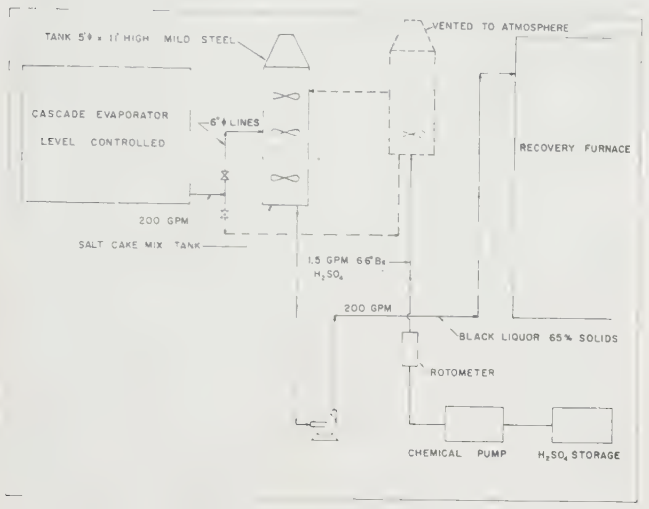

Fig. 1. Flow diagram

control but rather to get back to the more or less established sulfidity minimum.

This involves supplementing the normal salt cake make-up with additional sulfur. Substitutes for salt cake are reviewed in a paper by Pesch (*2*), and include most of the available sulfur compounds. Sulfuric acid was not specifically covered. Many schemes have been proposed, tried, and are in operation. The following are the more common and some of their drawbacks:

The addition of elemental sulfur to the furnace. Conversion efficiencies of sulfur to sulfide in the furnace have been notably low. This practice however has been used at times fairly extensively. There is always a difficult materials-handling problem involved. Further, although difficult to substantiate, some operators have strongly suspected this practice of causing reduced furnace wall life.

The addition of sulfur to the digester. This is an attempt to manufacture sulfide at the point of usage, namely in the digester or even in the wood chip. The chemical reactions postulated are (*3*):

$$6NaOH + 4S = 2Na_2S + Na_2SO_3 + 3H_2O$$

The degree to which this reaction occurs, if at all, under conditions prevailing in the digester, is the subject of considerable controversy and little evidence. In any case the presence of thiosulfates in the digester has been shown to have some bearing on increased corrosion rates. Again, materials handling is a problem.

The use of elemental sulfur in a system that combines digester and furnace additions has been described in a patent by Olin Mathieson which claims improved efficiencies (*4*).

Black liquor oxidation. A great deal of work has been reported in the literature on methods of black liquor oxidation and on results and advantages (notably Bergstrom, Trobeck, Tomlinson, Collins, and Wright). Probably the significant factor here is that the introduction of black liquor oxidation has served to increase the sulfidity level some 3 to 5% without make-up alterations. This represents a considerable amount of make-up sulfur if the increase is needed or if obtained through supplemental sulfur addition.

By-products and wastes are additional sources of sulfide sulfur. Sulfuric acid by-products from oil

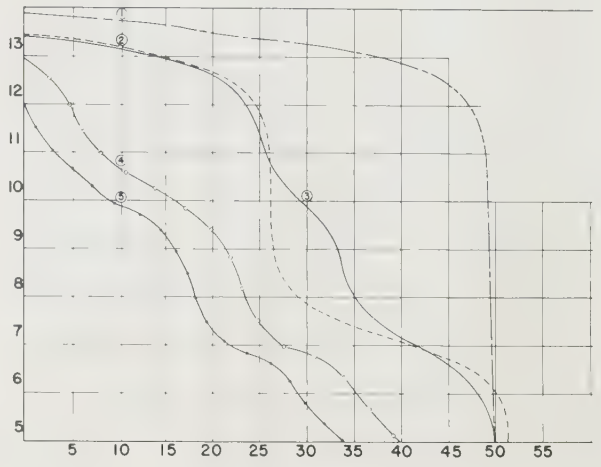

Fig. 2. Titrations

① 50 ml., 0.5 *N* NaOH; ② 50 ml., 0.5 *N* Na_2S; ③ 16.6 ml. each of 0.5 *N* NaOH, Na_2S, Na_2CO_3; ④ 5 g. 71% solids black liq. + 5 ml. 0.5 *N* NaOH; ⑤ 5 g. 71% solids black liquor.

refineries and from tall oil plants are excellent sources. Availability and contaminants are limiting factors.

None of these systems appeared practicable for total sulfur replacement in the quantities considered for the recovery of spent hardwood liquors. The presence of fairly large percentages of unreacted caustic soda in these spent liquors suggested the possible use of sulfuric acid as a source of supplemental sulfur. A large acid-producing unit in the area added impetus to this idea, since acid in the $12–$15 range is very attractive. Accordingly, the system (Fig. 1) was proposed for addition of the acid to the concentrated liquor.

Chemical costs vary from mill to mill, depending on location and freight costs. This discussion therefore is based on costs delivered to the Calhoun mill and will of course need to be revised when applied to any other mill.

The following are current costs in round figures:

Chlorine	$73
Salt cake	34
Caustic soda	66
Soda ash	41
Sulfuric acid	15
Sulfur	39

If we consider kraft mill make-up substitute using the relatively stable low priced sulfuric acid the stochiometric equations call for caustic soda at $42/ton or soda ash at $32/ton delivered to meet the salt cake price. Neither chemical meets this specification on the current market.

If, however, caustic soda is manufactured at the mill site as a by-product of chlorine manufacture, the cost

Table I. Mixing Problem

	Black liquor	*H_2SO_4*
Specific gravity	1.2	1.8
Temperature, °F.	200	70
Flow rate, g.p.m.	200	1.5–3
Viscosity, cp.	750	...
pH	11.4	Acid

picture changes considerably. The ratio of chlorine to caustic as used in the kraft mill bleach plant is roughly 2 to 1; the electrolytic decomposition of salt shows they are manufactured in the ratio of 1:1.125.

$$\underset{117}{2NaCl} \longrightarrow \underset{71}{Cl_2} + \underset{80}{NaOH}$$

The problem therefore of mill manufactured chlorine is the excess caustic. Assuming 140 lb. chlorine per ton kraft pulp there are thus about 87 lb. caustic per ton kraft in excess. It has been estimated that this caustic could be produced for $35 to $40 per ton, thus showing a substantial savings if used as kraft mill make-up with sulfuric acid as sulfidity control.

The savings are further enhanced if other pulping methods such as cold soda for hardwoods are in operation.

On a strictly sulfur basis, sulfuric acid sulfur at $45/ton does not compare too favorably with elemental sulfur at $39/ton. It is believed, however, that sulfuric acid sulfur converts to kraft mill cooking liquors more efficiently than does elemental sulfur.

ACID ADDITION TO BLACK LIQUOR

When titrating a strong base with a strong acid, the pH of the solution will decrease slowly, relative to the amount of acid added until a point is reached where the

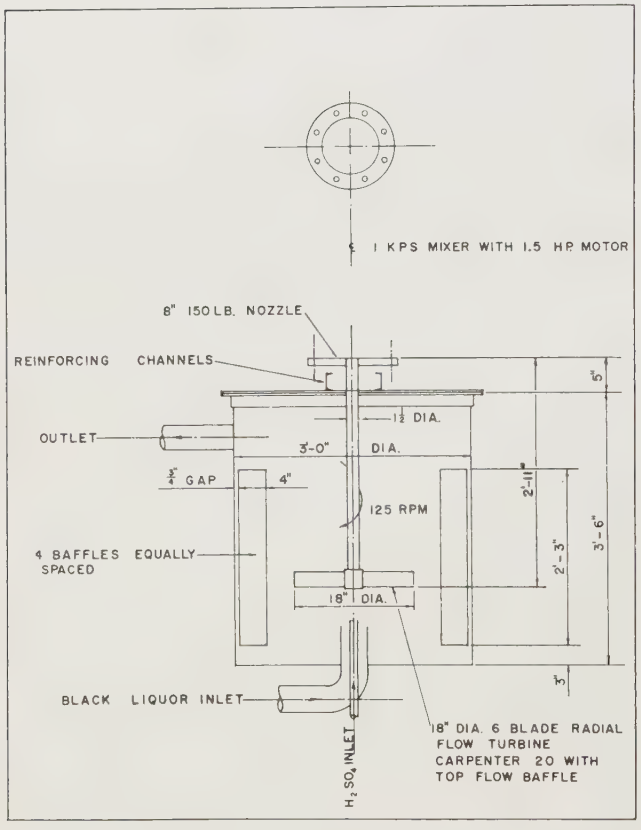

Fig. 3

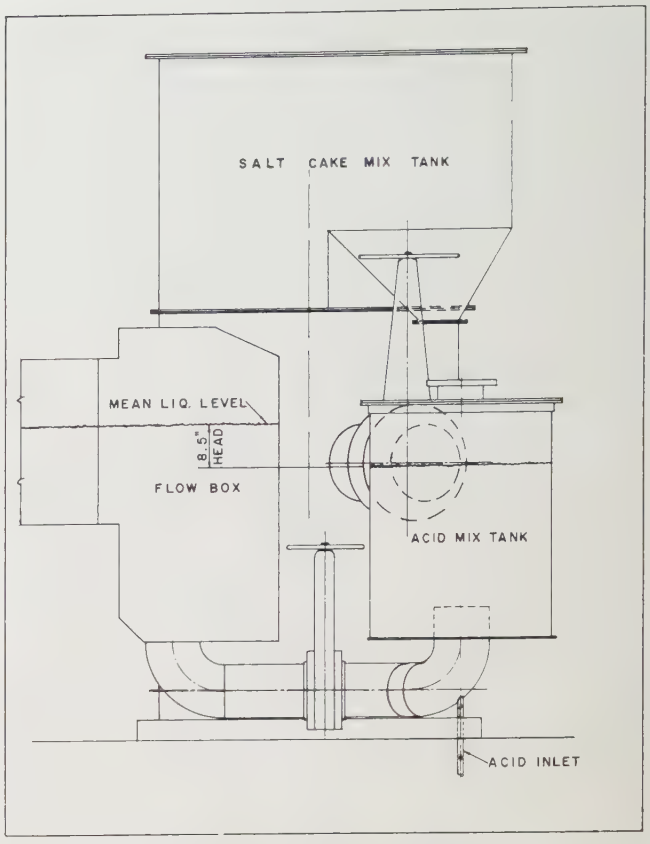

Fig. 4. Acid mixing system

$[OH]^-$ concentration in solution is small in relation to the $[H]^+$ concentration being added to the solution; the $[OH]^-$ decrease being due to the formation of undissociated HOH. The slope of the titration curve will increase rapidly at the above point until the reverse situation is reached where there is a large excess of $[H]^+$. The middle point between these two inflections is called the equivalence point or the point where $[H]^+ = [OH]^-$. This occurs at pH 7.0.

When adding acid to a solution of a salt of strong base and a weak acid, or to a solution containing the above and a strong base, the equivalence point will generally be at some pH above 7.0 due to hydrolysis of the salt.

Curve no. 1 of the graph in Fig. 2 is a titration of NaOH with a strong acid, the equation being:

$$NaOH + HA \longrightarrow NaA + HOH$$

The inflection point comes at a pH of about 12.0 and the equivalence point at 7.0.

Curve no. 2 is a titration of sodium sulfide with a strong acid. Here we have two equivalence points, pH 9.3 and pH 4.0, the equations being (*5*).

$$Na_2S + HA \xrightarrow{pH=9.3} NaA + NaHS$$

$$NaHS + HA \xrightarrow{pH=4.0} NaA + H_2S$$

Or, as Na_2S in water is hydrolized to caustic and bisulfide the equations would be written (*6*):

$$Na_2S + HOH \longrightarrow NaOH + NaHS$$

$$NaOH + NaHS + HA \xrightarrow{pH=9.3} NaA + NaHS + HOH$$

$$NaHS + HA \xrightarrow{pH=4.0} NaA + H_2S$$

The overall equation being:

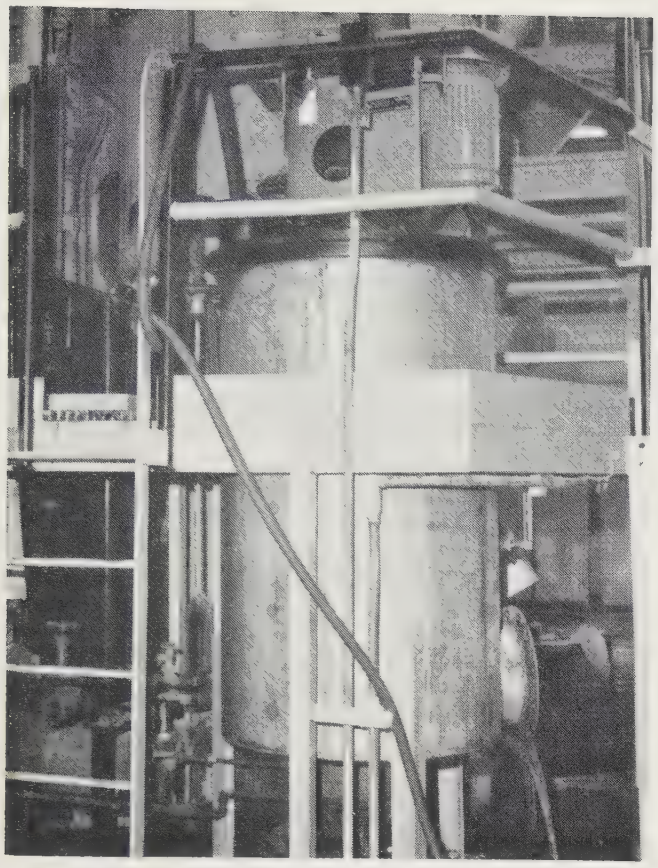

Fig. 5. Mixing tank

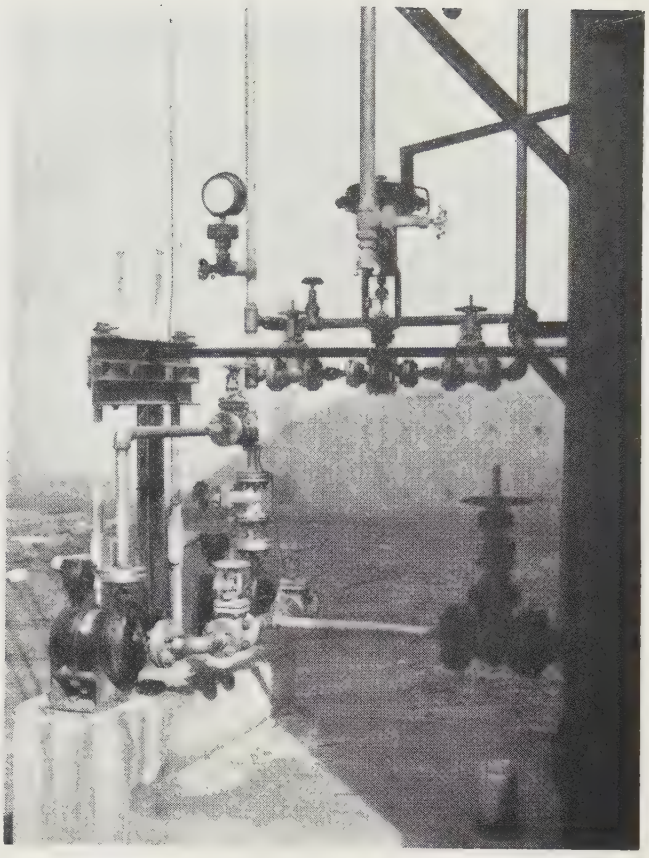

Fig. 6. Acid pumps and piping at tank

$$NaOH + NaHS + 2HA \xrightarrow{pH=4.0} 2NaA + H_2S + H_2O$$

Curve no. 3 shows the pH change on acid addition to a solution containing equal parts of chemicals present in black liquor, NaOH, Na_2S, Na_2CO_3. The upper portion of the curve from pH 13.2 to about pH 10.5 represents the neutralization of NaOH.

$$NaOH + HA \rightarrow NaA + HOH$$

At 8.3 the carbonate has been converted to bicarbonate and the sulfide is as NaHS:

$$Na_2CO_3 + HA \rightarrow NaHCO_3 + NaA$$
$$NaOH + NaHS + HA \rightarrow NaA + NaHS + HOH$$

At pH 4.0 the bicarbonate and bisulfide have been neutralized:

$$NaHCO_3 + HA \rightarrow NaA + CO_2 + HOH$$
$$NaHS + HA \rightarrow NaA + H_2S$$

Comparing curve no. 3 with no. 4 one can see corresponding equivalence points for caustic and carbonate. The slope of the curve at pH 4.0 (not shown) is not as steep for the black liquor as in the synthetic solution which is probably due to buffering by sodium organics. Curve no. 5 shows that there is very little caustic as such in the black liquor, therefore most of the titratable sulfide is present as NaHS.

It may be said then that in black liquor caustic is neutralized between pH 12.5 and 10.0 and the sodium carbonate at pH 8.3. Using sulfuric acid the equation would be

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$
$$2Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2NaHCO_3$$

From the foregoing discussion one would expect that the addition of sulfuric acid to black liquor containing a large amount of caustic would result in its conversion to Na_2SO_4 (salt cake). We have found this to be true to the extent that we have lowered our salt cake feed and that out white liquor sulfidities are higher. It has been said that the sulfide present in the black liquor would not be affected by the acid addition. Obviously at the point of addition of the concentrated sulfuric acid, hydrogen sulfide will be evolved but the gas will be reabsorbed as it is produced. We have detected very little sulfide loss above the acid mix tank.

APPLICATION

Investigational work in which acid was pumped to the salt cake mix tank indicated that the problem of applying this method of sulfidity control was strictly one of mixing. The probability of salting out of sodium sulfate in the evaporators and cascades predicated that the point of addition of the acid should be as close to the furnace as practicable. The mixing problem was then essentially as shown in Table I.

Equipment as shown in Fig. 3 was recommended for the job and was installed in accordance with the flow diagram of Fig. 1. The system consists of a by-pass line with a small acid mix tank between the cascade evaporator flow box and the salt cake mix tank so that the system could be cut into or out of the line without recovery furnace interruption. A suitable mixer was installed in the acid mix tank. Figure 4 shows the physical arrangement. Black liquor flows from the cascades through the flow box and screen down into the by-pass line, then up through the acid mix tank and overflows into the salt cake mix tank.

Sulfuric acid at 66° Bé. is purchased in tank-car lots.

Table II. Furnace Feed Analysis

All figures as g.p.l. Na_2O

Tests made	Time a.m. 10:00	a.m. 11:30	p.m. 1:40	p.m. 5:00	p.m. 7:00	p.m. 9:00	p.m. 11:30	a.m. 1:00	a.m. 3:00
pH (50% solution)	11.6	11.4	11.3	11.1	11.1	11.2	11.2	11.3	11.2
Sp. gr. @ 60°F.	1.429	...	...	...	...	...	...	...	...
Total solids, %	68.3	69.7	68.8	69.0	69.3	68.6	66.7	67.0	69.7
Sulfate	31.09	32.15	31.01	34.26	31.99	33.13	40.55	38.40	41.03
Sodium sulfide	16.96	15.33	22.92	21.63	22.44	25.90	23.05	25.37	26.86
Sodium hydroxide	14.29	16.53	11.25	6.79	5.03	6.40	2.94	4.43	4.54
Sodium carbonate	147.06	158.92	144.51	141.12	148.08	154.53	145.78	141.35	150.00
Total sodium	303.5	317.5	298.7	318.8	299.4	335.5	295.9	289.1	296.7
Total sulfur	75.02	75.76	73.88	80.70	77.47	79.27	78.52	83.55	83.46
Active alkali	31.25	31.86	34.17	28.42	27.47	32.30	25.99	29.80	31.40
Total alkali	178.31	190.78	178.68	169.54	175.55	186.83	171.77	171.15	181.40

NaOH: 9:00 a.m. to 12:00 p.m. no. 6 evaporator
H_2SO_4: 4:15 p.m. to 3:00 a.m.
Salt cake make-up:
65 lb./min. to 5:00 p.m.
35 lb./min., 5:00 p.m. to 3:00 a.m.

It is unloaded by air into a storage tank size 18 ft. in diam. by 20 ft. high, holding 36,000 gal. or four 8000-gal. cars. This tank is constructed of mild steel plate with a vent seal to eliminate moisture condensation and possible corrosion. It is equipped with a float operated level measuring device plus a pressure operated level recorder with remote chart at the recovery operating floor. Acid is pumped through a 1-in. stainless steel line to the recovery floor where it passes through a rotameter to the feed nozzle in the mix tank. Two Chempumps rated at 3 g.p.m. and a 40-ft. acid head are set in parallel for pumping the acid. Continuous operation is insured with the two pumps.

The mix tank is fabricated from Carpenter 20 stainless steel. It is 3 ft. in diam. by 5 ft. high. Agitation is accomplished with a Cleveland type mixing unit consisting of a six-bladed, 18-in. diam., top baffled turbine rotating at 140 r.p.m. about 6 in. above the black liquor inlet. A 3-hp. motor drives the agitator at full load. The acid feed nozzle is a piece of $^1/_2$-in. Carpenter 20 stainless steel pipe about 4 ft. long inserted through a packing gland and terminating about 3 in. below the turbine. It is removable for inspection and cleaning. The rotameter is an armoured type with magnetic indicator. The system is controlled by manual valve at the rotameter on the operating floor. A view of the acid mix tank and the pumping system is shown in Figs. 5 and 6.

Table III. Green Liquor Analysis

All Figures as g.p.l. Na_2O

Tests made	Time a.m. 11:30	p.m. 1:40	p.m. 5:00	p.m. 7:00	p.m. 9:00	p.m. 11:30	a.m. 1:00	a.m. 3:00
Sodium sulfide	25.60	24.32	24.32	24.32	21.76	28.80	27.52	27.52
Sulfate	1.12	1.04	1.04	1.12	1.04	1.52	1.76	1.36
Sodium hydroxide	22.08	19.20	17.28	16.32	13.76	16.32	15.68	15.04
Sodium carbonate	86.40	76.48	77.76	84.80	74.88	98.24	91.20	88.64
Sodium thiosulfate	0.87	0.70	...	0.77	0.87	...	...	0.96
Sodium sulfite	1.24	1.13	...	1.28	1.27	...	...	1.61
Total sodium	165.8	144.0	144.0	144.0	128.7	163.7	159.3	159.3
Total sulfur	26.91	26.55	25.29	25.93	24.81	31.77	31.67	30.19
Reduction, %	95.8	95.9	95.9	95.6	95.4	95.0	94.0	95.3
Total tit. alkali	134.08	120.00	119.36	125.44	113.60	143.36	134.40	131.20
Active alkali	47.68	43.52	41.60	40.64	38.72	45.12	43.20	42.56
Sulfidity,[a] %	23.0	24.5	24.6	23.4	23.2	24.1	24.7	25.3

NaOH: 9:00 a.m. to 12:00 p.m., no. 6 evaporator
H_2SO_4: 4:15 p.m. to 3:00 a.m.
Salt cake make-up:
65 lb./min. to 5:00 p.m.
35 lb./min., 5:00 p.m. to 3:00 a.m.

[a] [2(B − A)]/(C × 0.83).

Table IV. Black Liquor Before and After Make-up

Make-up	From cascades: Normal	From cascades: With NaOH	To furnace: Na_2SO_4	To furnace: $Na_2SO_4 + H_2SO_4$
Sodium, g.p.l.	283	278	307	303
Sulfur, g.p.l.	53	58	75	81
Solids, %	71	70	69	68
Active alkali, g.p.l.	37	34	33	29

SULFIDITY CONTROL

Nonsulfide bearing spent liquor from the hardwood mill is added to the black liquor at a fairly steady rate (50 g.p.m.) with a consequent uniform sulfuric acid demand. However, normal recovery furnace operation, and salt cake make-up, is based on liquor inventories

Table V. Yearly Comparisons of Cooking Liquor

	Year 1956	1957	1958	1959[a]
White liquor sulfidity	21.9	20.8	21.6	22.8
Salt cake make-up	151.4	141.4	148.4	88.9
Na_2SO_4 from hardwood mill	...	1.6	...	51.6
Sulfur from H_2SO_4	...	0.36	2.4	14.4
White liquor activity	83.6	83.9	83.7	83.9
Active alkali, lb./cu. ft.	6.95	6.98	7.00	6.99
Total alkali, lb./cu. ft.	8.31	8.32	8.36	8.33
Active alkali charge	6825	6862	7050	7147

[a] Period April to July inclusive.

which require changes for various reasons. For constant white liquor sulfidity therefore the acid requires adjusting upward during periods of low salt cake make-up and the reverse for periods of increasing white or green liquor inventory. The usual procedure then is to adjust the acid feed rate at the same time as salt cake make-up rates are changed.

Operating difficulties to date have been very minor. The temperature of the black liquor from the cascades rises some 8 to 10°F. with acid addition to about 208°F. This is further heated by direct steam to about 240° at the furnace nozzle. With temperatures kept at 198° cascades, 208° mix tank, 225° to pump and 240° to nozzle, no trouble has been experienced. Loss of mixing efficiency was found to be due to solids build up on the agitator. This was eliminated by periodic boiling with direct steam in the mix tank.

The entire system is handled by the power plant personnel.

RESULTS

Prior to the startup of the hardwood system, a trial was made in which caustic soda was added to the system at the multiple effect evaporator and the stoichiometric acid added to convert to salt cake. This 16-hr. trial served to test the equipment and as a check on chemicals. Acid was added at 1.35 g.p.m. and the salt cake make-up was reduced an equivalent amount. Analysis of furnace liquor feed is shown in Table II, and green liquor from the smelt dissolving tank in Table III. There was no significant change in sulfidity as tested at the smelt dissolving tank. Black liquor tests before and after chemical make-up averaged as shown in Table IV for soda and sulfur. It was realized that a few hours run on a system with a total Na_2O content in excess of 1,000,000 lb. was far from conclusive.

As a matter of interest, a further test was run in which acid only was added. Green liquor sulfidity increased to beyond 30% in about 8 hr. Furnace feed liquor pH did not fall below 10.2.

The hardwood mill was started early this year with the spent liquor being returned to the kraft mill weak black liquor system. Liquor tests for the period April to July inclusive were averaged and tabulated along with previous years in Table V. It is seen that we are not only providing sulfur to compensate for the recovered hardwood liquor but are also using sulfuric acid to gain an increase in sulfidity. This use is motivated more from the viewpoint of assisting an overloaded causticizing system than from pure quality control considerations. The month-to-month figures have shown wide fluctuations, as may be expected from a new system. With experience it is believed that the system will show improved economics.

It might further be noted that without this sulfuric acid system our hardwood mill could not operate, as stream pollution control equipment could not handle the additional B.O.D. load.

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Received Nov. 9, 1959. Presented at the 13th Alkaline Pulping Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Nov. 4–6, 1959.

The Application of a Centrifugal Water-Retention Test to Pulp Evaluation

EDWARD. F. THODE, JOSEPH G. BERGOMI, JR., and RENÉ E. UNSON

A new centrifugal method (designated the CWR Test) for estimating the swollen volume of papermaking pulp has been developed. This method gives excellent reproducibility and precision even with highly beaten pulps and has the potential advantage of permitting analytical interpretation of the process of centrifugal water extraction. Swollen volume values estimated by this method are about 10% lower than figures obtained by the filtration resistance method, presumably because of fiber deformation and "deswelling." Very good correlations with sheet strength properties were obtained when centrifugal water retentions and fiber-length indices were employed in a beating and refining study on sulfite pulp. It is concluded that this centrifuge method offers a fairly convenient method for the *empirical estimate* of the swollen volume of papermaking pulps, but that it cannot be considered as unbiased *measure* of swollen volume and must be viewed cautiously as a criterion of sheet strength.

Centrifugal methods for estimation or determination of the hydration or water-holding capacity of pulps go back at least as far as Hubert, Mathes, and Weisbrod in 1942 (*1*). Among those who have pursued this path, probably the most active and aggressive has been Jayme, who, with various co-workers, has published numerous articles on the subject in the past ten years (*2*).

After the centrifuge device and technique reported hereafter had been developed and was being evaluated, Jayme, Ghoneim, and Kruger (*2c*) published a paper giving results of comparisons of five different centrifuge cup assemblies for evaluation of beaten pulps. In that

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paper, a new cup consisting simply of a test tube-shaped thimble of nickel fourdrinier wire is claimed to give excellent reproducibility even with highly beaten pulps. This cup differs so much in geometry from the device hereafter described that it is thought desirable to identify the water-retention data from the two by

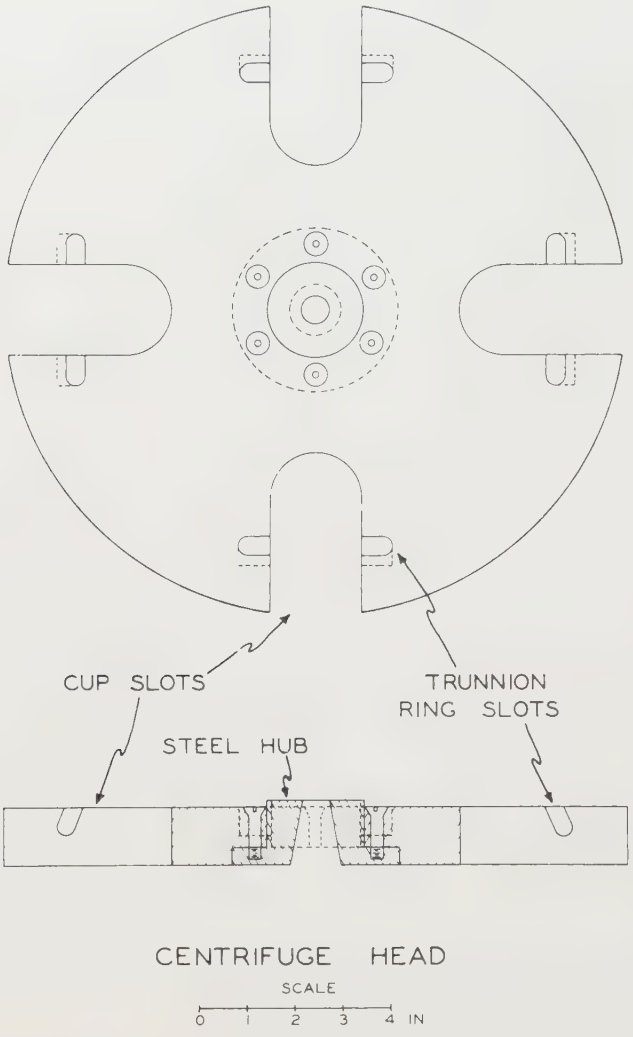

Fig. 1. Centrifuge head

different symbols. In this paper, therefore, the term, "water-retention value" (WRV) will be used in connection with data obtained by the various techniques proposed by Jayme; the term, "centrifugal water retention" (CWR), will be used in connection with the present method.

EFFECT OF CENTRIFUGAL FIELD

No definitive work has been performed to establish exactly what relative centrifugal force, F_c, is optimum for a centrifugal water-retention test. As is discussed in greater detail later, too low a value of F_c will fail to overcome the forces of capillary pressure in the inter-fiber voids and will thus result in a water-retention figure which is higher than the solely *intra*fiber water responsible for swollen volume. On the other hand, too high a value of F_c will result in fiber distortion and the loss of *intra*fiber water, with, consequently, a false low estimate of swollen volume.

After several attempts at evaluation of their WRV test at lower values, the German workers settled upon a value of F_c, of 3000 times the force of gravity (3000 g). This choice was presumably dictated by the capacity of the equipment available for the experiments. Even though it is suspected that 3000 g may eventually be determined to be too high a value of F_c, it was decided at the outset of the present work to design equipment which could at least reach this "bench

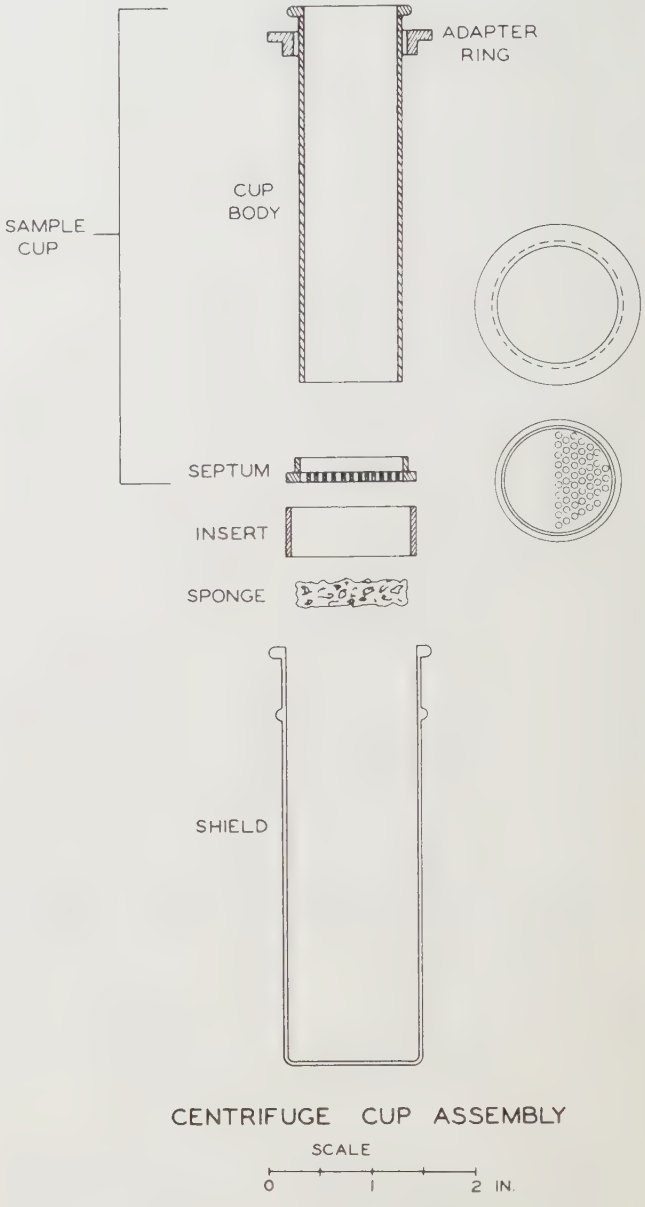

Fig. 2. Centrifuge assembly

(Not shown in the diagram is a disk of 100-mesh bronze screen which is placed over the septrum to prevent loss of fines in routine testing)

mark" value previously studied by Jayme and co-workers.

Basically, F_c is determined by two factors, the speed of rotation and the rotating radius of the pad of fiber from which water is being extracted. In English engineering units, the expression

$$F_c = 0.0000284\ RN^2 \qquad (1)$$

describes the relationship, where R is the rotating radius in inches and N is the rate of revolution in revo-

lutions per minute. Practical limitations are forced on R by the dimensions of the protective case of the centrifuge and by the strength of the metal parts of the centrifuge head. N is limited by the horsepower of the centrifuge motor, the frictional loss of energy in the bearings of the centrifuge and the "windage" loss, or energy consumed in air turbulence around the centrifuge head. This last item is by all odds the most important in determining the upper value of N which is attainable in a given system.

CENTRIFUGE EQUIPMENT

For the present study an International Centrifuge, Model V, size 2 was used. A special head assembly and also a special cup and shield assembly were designed and built. (See Glossary, page 512, for definitions of these terms.) The special head is a solid disk of magnesium alloy (Dow Metal Alloy FS 1-824), 13-in. diam. and $1^1/_4$ in. thick with a collar for attachment to the drive shaft and machined slots to accommodate four shields suspended from trunnion rings. (See Fig. 1.)

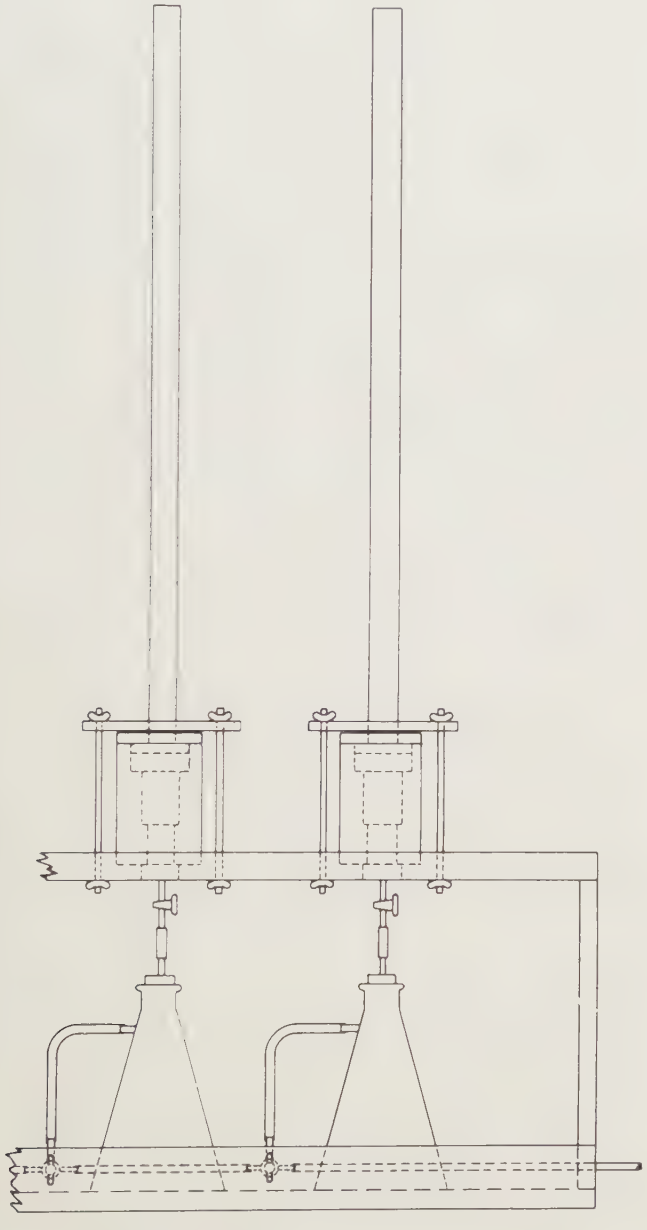

Fig. 3. Pad-forming stand

The special cup and shield assembly used was devised as follows: The upper $3^5/_8$ in. of a 1-in. o.d. brass test tube (International no. 327) was cut off and a flanged brass septum was press-fitted to the cut end of this upper part. The septum was drilled with $^5/_{64}$-in. holes on $^3/_{32}$-in. 60° centers; the holes are countersunk to provide virtually negligible land area. The peripheral flange of the septum is designed to provide a slip fit within an International no. 320 shield. In use, the flange rests upon a hollow cylindrical aluminum insert at the bottom of the shield, so that the mass of the septum, pulp sample, and cup is supported by the bottom of the shield. A sponge at the bottom of the shield to absorb the expressed water, an aluminum adapter ring at the top of the cup to steady it within the shield, and a cork stopper to prevent drying of the sample complete the assembly. An exploded dimensional diagram of the complete assembly is shown in Fig. 2. Not shown in the diagram is a disk of 100-mesh bronze screen which is placed over the septum to prevent loss of fines in routine testing.

EXPERIMENTAL PROCEDURE

Pad Making

To obtain reproducible results, and also in order to form pads of uniform fiber distribution so that eventual analysis of the water-extraction process would be possible, a very careful technique of pad formation by constant-rate filtration was employed. The equipment used consisted of a bank of four duplicate devices, each comprising a filter flask, a sample cup holder, and a flow tube or slurry reservoir. A schematic drawing of this setup is shown in Fig. 3.

Since all the tests were run in quadruplicate, the initial pulp preparation involved considerably more pulp than that required for a single centrifugal test pad. As a standardized procedure, the equivalent of 1.5 g. ovendry fiber in the form of slush pulp or wet crumb stock was weighed out and dispersed in 800 ml. of deionized water at 75°F. for 300 counts in a British disintegrator. Sufficient deionized water was added to the disintegrated pulp to bring the volume to 2 liters; the slurry was then transferred to a 4-liter flask and deaerated under vacuum for 4 hr. at constant temperature.

In order to form the four pads for a given run, four sample cups were clamped inside the sample holder of the pad-forming device and filled with deionized water to a level where the water could just be seen above the slurry reservoir tube. This served to prevent the passing of fibers through the sample cup septum when the slurry was poured into the tube. The equivalent of about 0.15 g. ovendry pulp, or about 200 ml. of slurry was poured into each of the four sample tubes, and the water was allowed to drain through. Control of the rate of drainage was accomplished with the stopcocks underneath the holders. Too fast a drainage rate causes channeling and excessive loss of fibers while a very slow rate causes poor pad formation, with much of the fibers clinging to the sides of the cups. The best drainage rate was found to be the point at which

Table I. Relative Pore Volumes of Classified Pulp Pads (Wet)

Pore radius, μ	Volume of pores, cc./g. dry fiber: 0-min. beating	Volume of pores, cc./g. dry fiber: 35-min. beating
<1	0.001[a]	0.002
1–2	0.040[a]	0.070
2–3	0.090	0.172
3–4	0.113	0.202
4–5	0.127	0.254
5–6	0.142	0.274
6–7	0.150	0.254
7–8	0.135	0.236
8–9	0.173	0.241
9–10	0.285	0.241
>10	6.257	10.930

[a] Estimated value, original data faulty.

the drainage water just begins to form a continuous stream. A slower initial rate of drainage was used for whole beaten pulps to minimize loss of fines.

Centrifuging

After all the slurry had drained from the sample reservoir, the vacuum was broken before air could strike through the pads. The cups were removed from the pad-forming device, placed in shields and, after balancing, placed in the trunnion rings.

For all runs, the current to the centrifuge motor was adjusted so as to bring the head up to the predetermined speed for the run in exactly 1.5 min. Similarly, at the conclusion of the predetermined centrifuging time, the braking device was applied continuously in such a manner as to maintain a uniform deceleration time of 2.5 min.

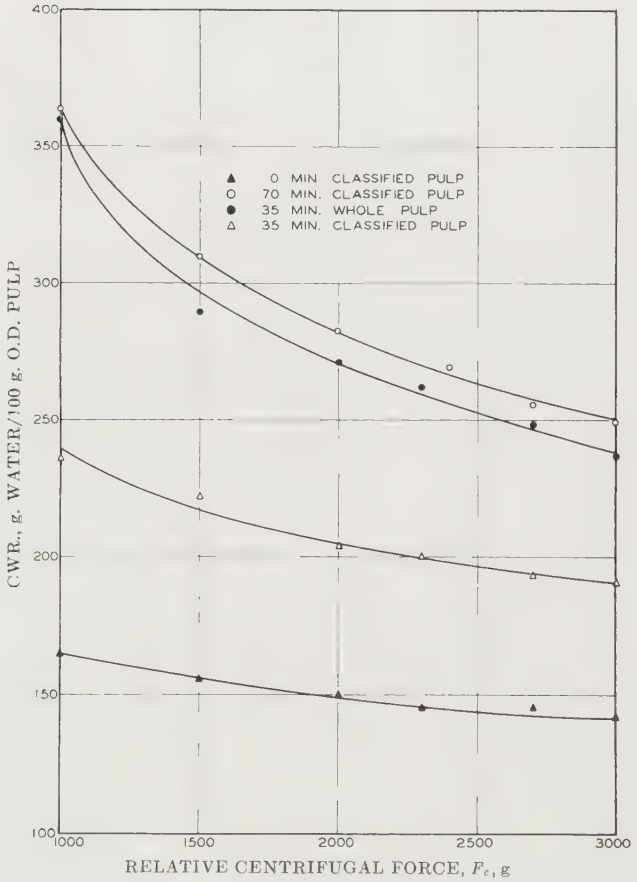
▲ 0 MIN CLASSIFIED PULP
○ 70 MIN. CLASSIFIED PULP
● 35 MIN. WHOLE PULP
△ 35 MIN. CLASSIFIED PULP
CWR., g. WATER/100 g. O.D. PULP
RELATIVE CENTRIFUGAL FORCE, F_c, g

Fig. 4. Influence of centrifugal force on water retention for various intervals in the Valley beater

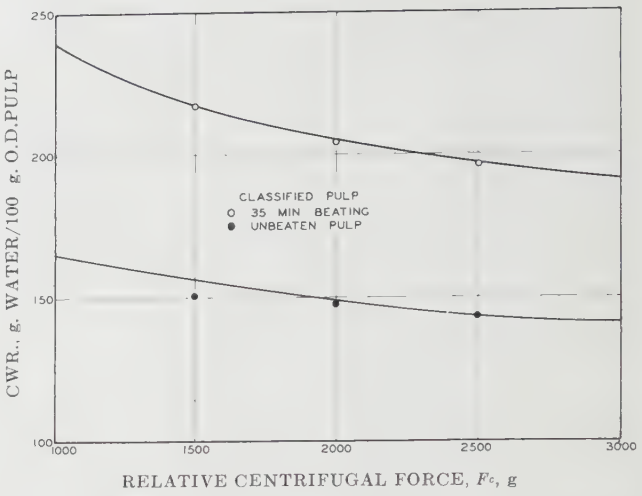

Fig. 5. Water-retention prediction based on pore volume data

Note: Data points computed from pore volume data, trend line taken from Fig. 4.

At the end of a run, the pads were rapidly transferred to tared weighing bottles with tweezers and weighed wet. The uncovered weighing bottles were then placed overnight in an oven at 105°C., subsequently cooled in a desiccator, and then the dry weight of the pads determined. The centrifugal water retention is defined by these weights as follows:

$$CWR = \frac{\text{wet weight} - \text{dry weight} \times 100}{\text{dry weight} - \text{tare}}$$

Relative Centrifugal Force

As was mentioned earlier, the effect of relative cen-

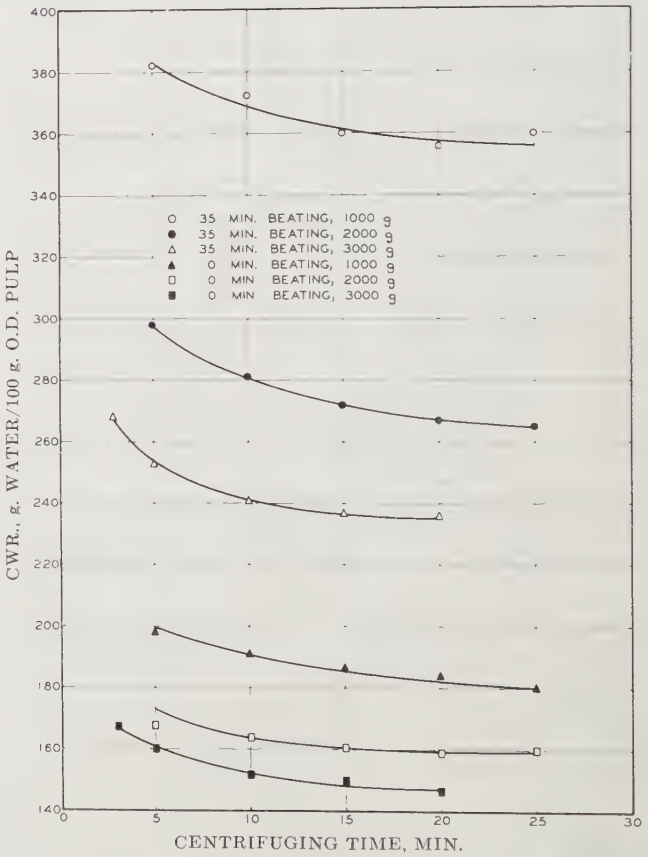
○ 35 MIN. BEATING, 1000 g
● 35 MIN. BEATING, 2000 g
△ 35 MIN. BEATING, 3000 g
▲ 0 MIN. BEATING, 1000 g
□ 0 MIN BEATING, 2000 g
■ 0 MIN BEATING, 3000 g
CWR., g. WATER/100 g. O.D. PULP
CENTRIFUGING TIME, MIN.

Fig. 6. Influence of centrifuging time on water retention—whole pulps

trifugal force on centrifugal water-retention values has not been given the attention it deserves. Previous workers have noted that the higher the value of F_c, the better the reproducibility of data and also the lower the values for water retention. The reasons for this have not been adequately analyzed.

Figure 4 shows the experimental results obtained when unbeaten classified (fines-free) pulp, two beaten classified pulps, and one beaten whole pulp were given water-retention tests at constant centrifuging time but variable relative centrifugal force. It may be seen that the CWR-value for unbeaten pulp is but little affected by an increase in F_c from 1000 to 3000 g, and there certainly would appear to be little or no effect of g-value above 3000 g. The moderately beaten (35 min. in the Valley beater) classified sulfite pulp shows significant effects of changes in F_c on CWR-value but appears to be leveling off at 3000 g. The highly beaten classified pulp and the moderately beaten whole pulp show strong effects of g-value which obviously will continue to be important over 3000 g.

These data alone should make us give pause and reflect on the inappropriateness of the test as a *fundamental* measure of some single basic property of pulp.

An attempt to quantitatively analyze the shape of these curves was made by first obtaining pore size distribution data on the unbeaten and 35-min. beaten classified pulps. These pore size data are listed in Table I.

It may be seen that, as would be expected, the total volume of interfiber pores in the 1 to 10 μ range is larger for the beaten pulp than for the same pulp unbeaten. If now, it is assumed that water is retained in some of the interfiber pores because of capillary suction and if it is assumed that capillary suction will only be effective in those pores of such size that P_c (the capillary pressure) is equal to or greater than F_c, then the proportion of these pores in which capillary suction is actually effective may be estimated from two values of CWR and the two corresponding values of cumulative pore volume. For the unbeaten pulp, this estimate came out to be 17.2% and for the 35-min. classified pulp, 27.3%. These last figures can be used to *predict* the shape of the CWR-vs.-F_c curves from experimental pore volume data. Figure 5 shows such prediction. The solid lines are the smoothed curves *fitting the data* in Fig. 4; the open circles are the values *predicted* from cumulative pore volumes.

While the good agreement of the points predicted from pore-volume determinations with the curve obtained from experimental water-retention data is not proof of the validity of the capillary suction hypothesis, it is strong indication of the importance of this factor. This also provides a reasonable explanation of the very marked effect of g-value on water retention for highly beaten pulps and those containing much fines. Certainly, in such cases, there is a sizable volume of interfiber voids in the range below 5 μ in diameter. To discharge the finer of these against the force of capillary suction would require relative centrifugal forces much in excess of 3000 g. However, this does not mean that F_c values over 3000 g are considered desirable for this test because the factor of fiber distortion may become quite severe at higher centrifugal forces.

Time of Centrifugation

In Fig. 6 are shown the data for CWR as a function of centrifuging time for various values of relative centrifugal force. As may be expected, more and more water is extracted from the pulp as time goes on, but at higher g values the curves level off reasonably well, even for beaten pulps, after 15 min. It is a bit difficult to explain the rather long period of centrifuging time required to reach a reasonably stable water content, inasmuch as fluid flow calculations show that even 1 μ open-end capillaries should discharge completely in about 1 min. Presumably, this is a matter of the complication of two-phase (water and air) flow through the bed with unanalyzed resistances to flow being generated at constrictions by the forces of surface tension.

Standardized Procedure

On the basis of the foregoing information plus tests showing excellent reproducibility of results, it was decided that the standardized procedure for the CWR test would involve centrifuging a 0.15-g. sample (in quadruplicate) for 15 min. at a relative centrifugal force of 3000 g. It is fully realized that all of these specified quantities are subject to change, as further information contributes to our basic understanding of the centrifuging process and of the real meaning of the desired property of swollen specific volume.

COMPARISON WITH FILTRATION RESISTANCE METHOD

Table II lists the CWR values, a few WRV values, and filtration resistance specific volume as a function of beating time in the Valley beater, using Western bleached sulfite pulp. Data are given for both whole and classified pulps. It may be seen that both the CWR test and the filtration resistance measurement indicate a higher swollen volume of whole pulp as compared with classified pulp. A direct comparison of the two tests is displayed in Fig. 7, where water-retention figures have been converted to specific volume by addition of the constant 0.62 to account for the volume of the cellulose. In this figure, swollen volume is plotted as a function of time of beating.

It is an inescapable experimental fact that the estimate of swollen volume for well-beaten (in the Valley beater) pulp with fines removed is *lower* by the centrifugal water-retention test than by the filtration resistance test. This must be considered a fundamental defect in the centrifugal water-retention test (whether it be by the Jayme technique or the CWR method) and is probably the result of fiber deformation under the applied stress of the test.

Wet fibers are readily deformed under the action of either centrifugal forces, as in the centrifuge test, or fluid drag forces, as exhibited in the filtration test. The order of magnitude of compacting pressure which acts on the fiber bed in the centrifuge test is about 100 g. per sq. cm. This corresponds to the final fluid pressures which act on part of the fiber bed during the last few seconds of the filtration test. It is possible, if fibers deform with a resulting decrease in volume during centrifuging, that some deswelling may also occur in the filtration method.

There are two major factors which may influence the CWR-value: (1) retention of some interfiber water, (2) deswelling of the fibers. On the other hand, the single major factor which could influence specific volume determined in the filtration method would be deswelling of the fibers. In the filtration test, compacting pressure on the wet fibers varies from essentially zero at the face of the mat to a maximum of about 100 g. per sq. cm. at the downstream face of the mat. In addition, for a major portion of the filtration time (about 10 min.) the fibers are subjected to considerably lower compacting pressures. In contrast, the compacting pressure in the CWR test exerts its influence on all of the fibers for the entire 15-min. duration of the test. Therefore, it is possible that fiber deswelling occurs to a much greater extent in the centrifuge test, and eventually this deswelling becomes more important than the interpore water retained in the mat.

If the CWR and filtration specific volume data from both beater runs are cross-plotted, the points will be found to lie in excellent agreement with a line of slope one and intercept 0.88 on the filtration specific volume axis. The coefficient of correlation is 0.980.

Such a plot is not displayed because there is no theoretical significance to the intercept. The reader will recall the arbitrary selection of the conditions of the CWR test.

On the other hand, the excellent linear correlation of CWR and specific volume is very encouraging since it

Table II. Centrifugal Water Retention and Filtration Specific Volume of Beaten Pulps

Sample	*CWR, g./g.*	*WRV, g./g.*	*CWR spec. vol., cc./g.*	*Filt. spec. vol., cc./g.*
Whole pulp				
0 min.	1.47	...	2.09	2.26
5 min.	1.70	...	2.32	2.67
20 min.	2.04	...	2.66	2.94
35 min.	2.40	...	3.02	3.10
50 min.	2.71	...	3.33	3.78
70 min.	2.77	...	3.39	3.62
Classified stock				
0 min.	1.42	1.44	2.04	2.31
5 min.	1.55	...	2.17	2.40
20 min.	1.76	...	2.38	2.62
35 min.	1.91	1.88	2.53	2.85
50 min.	2.13	...	2.75	2.90
70 min.	2.50	2.35	3.12	3.33

does suggest that the comparatively simple centrifuge test yields a figure closely and consistently related to the desired value of specific volume. As long as the basic limitations of the test are kept clearly in mind it can be very useful in providing an accurate estimate of *relative* swollen specific volumes.

RELATION TO SHEET PROPERTIES

It is clearly recognized by many workers that as fibers are beaten or refined, the degree of swelling increases. Removal of the primary wall, fibrillation of the fiber surfaces, and the opening up of the inner fiber structure are all factors which permit increased swelling as water penetrates more and more into the amorphous areas. It is a well-accepted fact that increased swelling results in increased wet-fiber flexibility, which in turn permits more intimate contact of fiber surfaces during sheet formation. The final result in the dry paper is more interfiber bonding with generally increased strength properties. Because there is no presently available technique for direct measurement and interpretation of wet-fiber flexibility, the degree of swelling of the fibers is used as a measure of fiber flexibility. However, degree of swelling, whether determined by the centrifuge method or by the filtration technique, includes all the water immobilized by the fiber, such as water in the lumen and water in the interfiber pores. Presumably, wet flexibility of the fibers is more directly related to water which penetrates into the cell-wall structure. Therefore, an appreciable

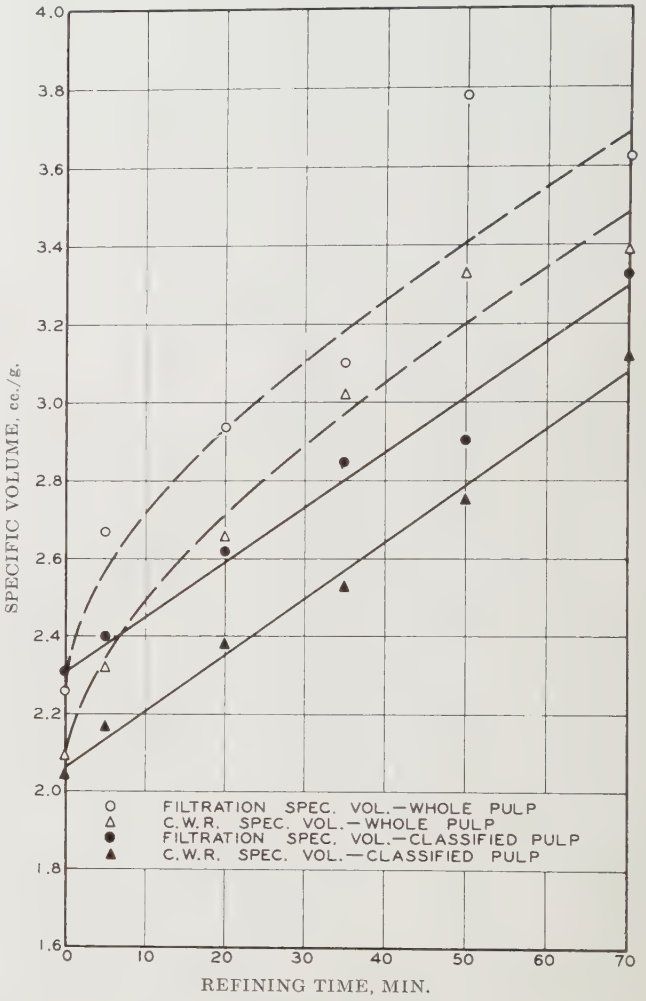

Fig. 7. Influence of Valley beater processing on swollen specific volume

fraction of the water which is characterized by degree of swelling tests would have little or no relationship to fiber flexibility.

Despite this drawback, it may be assumed that the water measured in the CWR test is *proportional* to that which plasticizes the cell wall, so that this test may be used as an *estimate* or an *indicator* of a basic phenomenon relative to sheet strength.

USE OF CWR TEST IN REFINING STUDY

Since fiber length and "hydration" are among the two most important wet fiber properties which determine the strength properties of a dry sheet of paper, it has often been suggested that tests of a measure of hydration and of fiber length be used for prediction

Table III. Summarized Data

Relation of Centrifugal Water Retention and Fiber-Length Index to Sheet Strength

Ball mill processing time, min.	*Mead refiner processing time,[a] sec.*	*CWR, g./100 g. ovendry fiber*	*FLI*	*Tensile strength, lb./in.*	*Tear factor*	*MIT fold*
0	0	106	1.493	8.0	1.19	3
0	5	126	1.211	11.8	1.32	5
0	15	159	1.007	17.3	1.23	22
0	15	159	...	16.5	...	21
0	15	149	...	14.9	...	16
0	30	181	0.796	21.2	1.01	92
0	30	179	...	21.0	...	70
0	30	177	...	20.6	...	50
0	45	216	0.733	24.5	0.94	238
0	45	205	...	23.9	...	196
0	60	219	...	26.7	...	307
15	0	148	1.248	14.0	1.39	14
15	5	174	1.083	18.0	1.67	45
15	15	190	0.949	21.4	1.07	114
15	30	222	0.769	24.8	0.85	299
15	45	243	0.677	25.1	0.85	493
30	0	162	1.264	15.1	1.33	15
30	5	178	1.068	19.2	1.31	36
30	15	192	0.890	22.4	0.95	74
30	30	224	0.752	25.8	0.82	177
45	0	184	1.265	17.9	1.17	42
45	0	189	...	17.9	...	52
45	0	184	...	18.7	...	75
45	5	198	1.023	22.4	0.99	186
45	5	195	...	21.2	...	147
45	5	195	...	22.5	...	164
45	15	219	0.876	27.0	0.87	332
45	15	213	...	23.5	...	291
45	15	217	...	24.9	...	360
45	30	245	0.752	27.0	0.76	509
45	30	235	...	26.5	...	450
45	30	245	...	27.2	...	584
0	0[b]	107	1.545	7.9	1.09	2
0	5[b]	121	1.223	10.2	1.35	3
0	15[b]	138	1.071	13.8	1.31	8
0	30[b]	160	0.972	16.8	1.18	15
0	45[b]	173	0.869	21.1	1.07	39

[a] Refining at 2% consistency.
[b] Refining at 3% consistency.

of strength properties. Wier (*3*), for example, reported a brief study employing a modification of the water-retention value test and a fiber-length index test in which the differing action of various refiners on cutting and on hydration could be observed through analysis of the comparative results of the two tests.

This approach can be carried a step farther. It is now fairly well established that the four dry properties of the sheet most important in establishing tensile strength are the fiber length, the intrinsic fiber strength, the bonding (bonding strength appropriately determined), and formation. If one can obtain an experimental system where formation of handsheets is kept reasonably consistent, and if one uses a single source of fiber without deteriorating the fiber strength upon refining, it may be argued that the two remaining

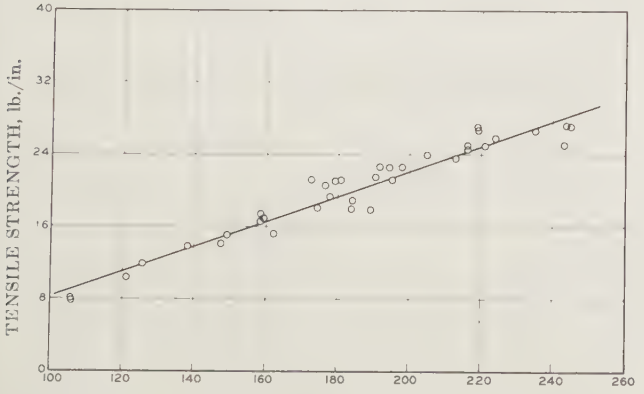

Fig. 8. Correlation of tensile strength and centrifugal water retention (ball mill and Mead Refiner study)

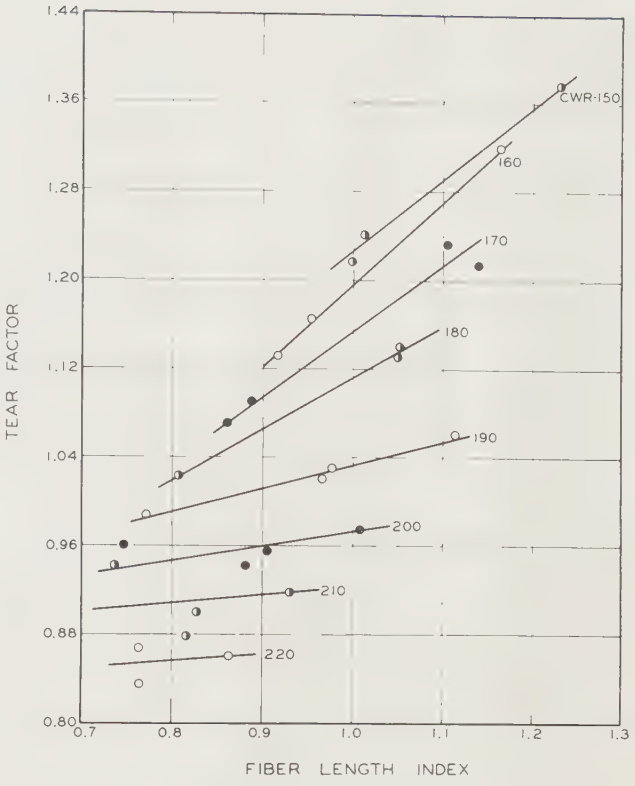

Fig. 9. Interpolation of centrifugal water-retention data on relation between tear factor and fiber-length index

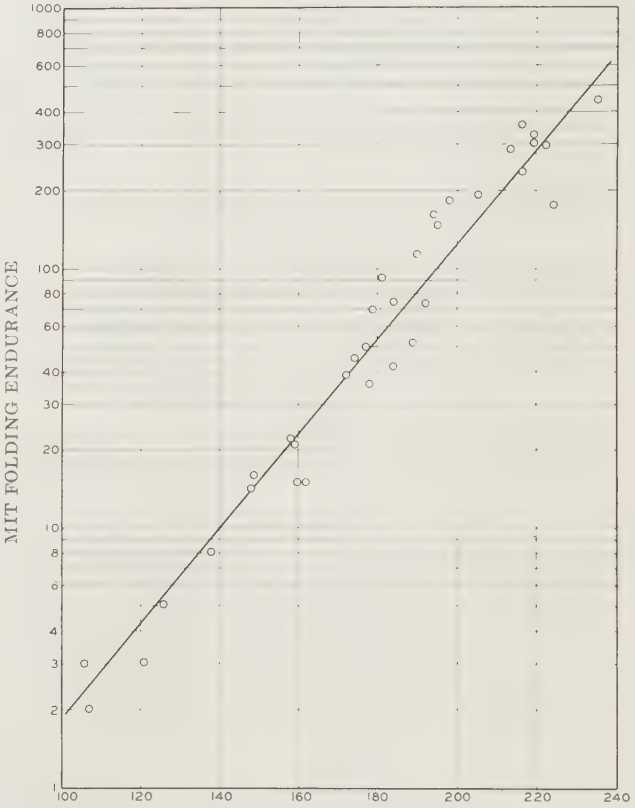

Fig. 10. Relation between MIT folding endurance and centrifugal water retention

important factors may be measured in the wet state. If the amount of swelling of the fibers is related to the fiber bonding potential dry, then the CWR test may be used as an approximation of such bonding potential. A ready measure of fiber-length distribution such as the deMontigny grid test (*4*) can complete the picture.

Experimental Procedure

Samples from the same lot of unbleached softwood sulfite pulp were subjected to successive treatments in a laboratory ball mill and in a Mead laboratory refiner. It may be expected that the action of the ball mill would be quite close to pure hydration, whereas the Mead refiner could accomplish considerable cutting. Ball milling was performed on 100-g. batches of fiber according to TAPPI Standard T 224 sm-45 (*5*). The Mead refiner was operated with a 5-lb. weight on the lever arm using a recirculating batch size of 4 liters at 2% consistency. One run was made at 3% consistency. Fiber-length index (FLI) tests were run according to the procedure of deMontigny and Zborowski (*4*). Centrifugal water-retention values were obtained in the apparatus and according to the method previously described. Handsheets were prepared according to TAPPI Standard T 205 m-53 (*5*), and the indicated physical tests performed.

A summary of the refining times used and of the experimental results may be found in Table III.

Relation of CWR and FLI to Handsheet Strength Properties

As shown in Fig. 8 the tensile strengths of all of the handsheets prepared in this investigation were related to the centrifugal water retention of the refined pulp to a highly significant degree. The correlation coefficient of the regression curve plotted in this figure is 0.968 and has a high degree of statistical significance. The correlation is so good in fact, that one must suspect that the known effects of fiber length and of formation on tensile strength must be compensating for each other over the span of tensile values and/or degrees of refining here reported.

For an analysis of tearing strength, an interpolation of the data reported in Table III was necessary. Various convenient levels of centrifugal water retention were arbitrarily selected. The refining time corresponding to such CWR values was then determined from a plot of CWR versus refining time for the various runs. From corresponding plots of FLI versus refining time and tear versus refining time, the corresponding values of those two variables were interpolated. Figure 9, therefore, represents the relationship between tear factor and fiber-length index with centrifugal water retention as the parameter.

The shift of importance from hydration to cutting as one moves in the direction of greater hydration may be observed from the trend lines in Fig. 9. This behavior is consistent with our present knowledge of the mechanism of tear. At the higher centrifugal water retentions, there is presumably a great deal of bonding in the sheet. Thus, the mechanism of tear is likely to be largely the matter of the breakage of fibers rather than the pulling out of fibers. Little influence of fiber length on tear would therefore be expected at such levels of hydration. On the other hand, at the relatively low levels of hydration found at centrifugal water retentions of 150 or 160, there must be a great deal of pulling out of fibers during the tear test. The length of such fibers would then be critical to the energy expended in the test.

Figure 10 shows, on semilogarithmic co-ordinates, the correlation between MIT folding endurance and centrifugal water-retention values. Since MIT folding endurance is believed to be strongly affected by bonding, such a fine correlation may well be expected. However, at the present time, we have insufficient basic knowledge of the mechanism of this test to apply a rigorous analysis to the indicated results.

CONCLUSIONS

A centrifuge technique has been devised for estimating swollen specific volume of wood pulp fibers rapidly and with good precision. The method works well both for unbeaten and for highly beaten pulps. However, because of effects of incomplete removal of interfiber water and possible removal of some intrafiber water by fiber deformation, slightly different values are obtained from this method than from the filtration method for estimating swollen specific volume.

Centrifugal water-retention values so obtained correlated very well with tensile strength tests on handsheets over a wide range of beating. Indications are that this test may be combined with a simplified fiber-length test for prediction of various sheet properties.

GLOSSARY

Head. A rotating structural member attached to the drive shaft of a centrifuge. Its purpose is to hold several objects or devices to be subjected to the centrifugal field at a constant rotating radius and in such a manner that no appreciable bending stress is applied to the drive shaft.

Cup. Container for the liquid or suspension to be centrifuged.

Shield. A metal cylinder of sufficient size to accommodate the cup; principally used to support the cup, to retain the contents in case of spillage or breakage, and to protect the contents of the cup against the drying effect of air motion. The shield may have lugs welded on the side which fit in slots in the periphery of the head; it may have a collar for attachment to the head by means of a trunnion ring, or it may be an integral part of the head.

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Received Jan. 20, 1960. Presented at the 45th Annual Meeting of the Technical Association of the Pulp and Paper Indusry, held in New York, N. Y., Feb. 22–25, 1960.

The authors wish to acknowledge the co-operation of the member companies of the Pulp Evaluation Group in supporting the majority of the work here reported. Thanks are due to Bruce D. Andrews for the obtaining of filtration resistance data and to William L. Ingmanson for criticism and helpful advice.

ASSOCIATION NEWS AND EVENTS

National Conferences

1960

Eleventh Coating Conference, May 23–25, 1960, Edgewater Beach Hotel, Chicago, Ill.

Pulp Bleaching Conference, June 14–16, 1960, Edgewater Beach Hotel, Chicago, Ill.

Ninth Statistics Course, Aug. 8–19, 1960, N. C. State College, Raleigh, N. C.

Fourteenth Alkaline Pulping Conference, Aug. 22–24, 1960, Multnomah Hotel, Portland, Ore.

Forest Biology Conference, Aug. 24–27, 1960, New Washington Hotel, Seattle, Wash.

Eleventh Testing Conference, Sept. 27–29, 1960, Pantlind Hotel, Grand Rapids, Mich.

Fifth Deinking Conference, Oct. 5–7, 1960, Conway Hotel, Appleton, Wis.

Tenth Corrugated Containers Conference, Oct. 10–13, 1960, Royal York Hotel, Toronto, Ont.

Fifteenth Plastics Conference, Oct. 17–19, 1960, Syracuse Hotel, Syracuse, N. Y.

Fifteenth Engineering Conference, Oct. 24–28, 1960, Robert Meyer Hotel, Jacksonville, Fla.

Fundamental Research Conference, Nov. 3–5, 1960, Northampton Hotel, Northampton, Mass.

1961

46th Annual Meeting, Feb. 19–23, 1961, Commodore Hotel New York, N. Y.

Twelfth Coating Conference, May 15–17, 1961, Statler-Hilton Hotel, Buffalo, N. Y.

Twelfth Testing Conference, Aug. 15–18, 1961, Queen Elizabeth Hotel, Montreal, Que.

Eleventh Corrugated Containers Conference, Sept. 11–13, 1961, St. Francis Hotel, San Francisco, Calif.

Fourteenth Mechanical Pulping Conference, Sept. 19–21, 1961, Edgewater Beach Hotel, Chicago, Ill.

Symposium on Formation and Structure of Paper, Sept. 25–29, 1961, B.P.B.M.A., Oxford, England.

Sixteenth Plastics Conference, Oct. 9–11, 1961, French Lick Sheraton Hotel, French Lick, Ind.

Sixteenth Engineering Conference, Oct. 15–19, 1961, Shoreham Hotel, Washington, D. C.

Fifteenth Alkaline Pulping Conference, Nov. 1–3, 1961, Rice Hotel, Houston, Tex.

1962

47th Annual Meeting, Feb. 18–22, 1962, Commodore Hotel, New York, N. Y.

Thirteenth Coating Conference, May 14–16, 1962, Netherland-Hilton Hotel, Cincinnati, Ohio.

Thirteenth Testing Conference, Sept. 18–20, 1962, Benjamin Franklin Hotel, Philadelphia, Pa.

Seventeenth Engineering Conference, Oct. 14–19, 1962, Queen Elizabeth Hotel, Montreal, Que.

Twelfth Corrugated Containers Conference, Oct. 23–26, 1962, Statler-Hilton Hotel, Boston, Mass.

Sixteenth Alkaline Pulping Conference, 1962, Savannah, Ga.

1963

Fourteenth Coating Conference, May 19–22, 1963, French Lick Sheraton Hotel, French Lick, Ind.

Thirteenth Corrugated Containers Conference, Oct. 22–25, 1963, Statler-Hilton Hotel, Detroit, Mich.

Eighteenth Engineering Conference, 1963, Chicago, Ill.

Corrosion Committee—Pulp Purification Subcommittee

The Pulp Purification Subcommittee of the TAPPI Corrosion Committee is planning a meeting devoted to the subject of "Corrosion Problems in Pulp Purification." This meeting is scheduled for June 13, 1960, at the Edgewater Beach Hotel, Chicago, Ill. This will be the day prior to the start of the Pulp Purification Conference to be held at the Edgewater Beach Hotel June 14, 15, and 16. It would allow interested people to attend both our meeting and the Pulp Bleaching Conference.

The present plans for the subcommittee meeting call for discussion, question-and-answer type sessions in the morning and afternoon. We will expect to discuss the uses of the various metals in the morning meeting and the plastics, elastomers, brick, and tile in the afternoon. We hope to have representatives present from the mills who will outline problems and technical representatives to discuss, answer and recommend materials of construction, fabrication, and installation. The subcommittee is comprised of people who can discuss stainless and other high alloys, titanium, plastics, brick, and tile and fabrication. We will plan on calling others from outside our group to increase our coverage of this very important subject.

Please address all questions to E. W. Hopper or A. O. Caldwell, Service Erection Co., 1673 Washington Road, Pittsburgh 28, Pa.

This meeting will be held if we receive enough indications that it will be well attended. Responses to date tend to show interest and enthusiasm for the session. If you plan on attending and participating in this meeting, will you please advise E. W. Hopper, 905 Union Trust Bldg., Pittsburgh 19, Pa.

Chemical Engineering Problems

The subcommittee on Chemical Engineering Problems, TAPPI Project No. 780, has as its primary purpose the preparation of a workbook of problems and their solutions. L. C. Jenness, University of Maine, Orono, Me., chairman of the subcommittee, is earnestly soliciting from members and friends of TAPPI Chemical Engineering problems and their solutions to supplement the 35 problems already on hand.

The workbook is to be offered to educational institutions for their use in discussions and examinations on pulp and paper technology in chemical engineering curricula.

The material should be suitable for use by third and fourth year as well as graduate students. It is especially important that the problems lend themselves to solution by mathematical methods rather than by descriptive means.

Will those interested in submitting problems and their solutions in the categories of stoichiometry, thermodynamics, fluid mechanics, heat transfer, mass transfer, process control, kinetics, combustion, economy balance and process design please send them in quadruplicate to Professor L. C. Jenness, Head of Chemical Engineering Dept., University of Maine, Orono, Me.

Fifth TAPPI Deinking Conference

E. F. Andrews, International Paper Co., Niagara Falls, N. Y., chairman of the Deinking Committee, announced plans for the forthcoming Fifth Deinking Conference to be held on Thursday and Friday, Oct. 6 and 7, 1960, at the Conway Hotel, Appleton, Wis.

The conference committee is comprised of J. D. Allen, Bergstrom Paper Co., Neenah, Wis., chairman; (2) H. E. Stevens, Ward Paper Co., Merrill, Wis., treasurer; (3) M. A. Lefevre, Marathon Div., American Can Co., Menasha, Wis., secretary; (4) M. R. Kinne, Sealright-Oswego Falls Corp., Fulton, N. Y., technical program chairman; (5) C. G. Sisler, Bergstrom Paper Co., Neenah, Wis., mill tours and transportation chairman.

Arrangements for worthwhile papers are being made and will be announced at a later date. Visits through The Institute of Paper Chemistry and the Bergstrom deinking operations have already been scheduled.

Empire State

The technical program for the Whiteface Conference, Lake Placid, June 9–11, 1960, has been released by the Empire State Section.

FRIDAY, JUNE 10, 1960—9:30 A.M. TO 12:30 P.M.

1. "The Seas Grow Calmer," by John L. Harvey, Deputy Commissioner, Dept. of Health, Education, and Welfare, Food and Drug Administration.
2. "Food Additives Amendment Problems of a Packaging Material Manufacturer," by C. R. Calkins, Riegel Paper Corp., Milford, N. J.
3. "A Review of the Activities of the Food Additives Liaison Committee," by R. C. Crain, APPA-NPA, Rhinelander Paper Co., Rhinelander, Wis.
4. "The Food Additives Amendment and Paper Packaging," by Ralph T. Russell, Microbiological & Biochemical Research, Syracuse University Research Institute, Syracuse, N. Y.
5. "The Use of Colors in Food Packaging Paper," by E. I. Stearns, American Cyanamid Co., Bound Brook, N. J.

SATURDAY, JUNE 11, 1960—9:30 A.M. TO 12:30 P.M.

1. "Accelerated Drying on the Paper Machine," by Anthony V. Tortora, Dilts Div., Black-Clawson Co., Fulton, N. Y.
2. "High Velocity Installations," by Paul Goldner, J. O. Ross Engineering Co., New York, N. Y.
3. "High Velocity Drying," by Bernard J. Twisdale, Gould Paper Co., Lyons Falls, N. Y.
4. "Electric Infrared Heating in the Paper Industry," by W. L. Thomson, Edwin L. Wiegand Co., Chromalox Div., Pittsburgh, Pa.
5. Junior Awards.

FRIDAY WORKSHOP SESSION ON FOOD & DRUG ADMINISTRATION —2:00 P.M.

Panels

1. Government Aspects and Viewpoints
   Panelists:
   John L. Harvey, Government
   R. C. Crain, APPA-NPA
2. Manufacturers Aspects and Viewpoints
   Panelists:
   Ralph Russell, Syracuse University
   C. R. Calkins, Riegel Paper Corp.
   Dr. E. I. Stearns, American Cyanamid Co.

SATURDAY WORKSHOP SESSION ON DRYING—2:00 P.M.

Panels

1. High Velocity Air Drying
   Panelists:
   Anthony V. Tortora, Dilts Div., Black-Clawson
   Paul Goldner, J. O. Ross Engineering Co.
   Bernard J. Twisdale, Gould Paper Co.
2. Infrared Drying
   Panelist:
   W. L. Thomson, Edwin L. Wiegand Co., Chromalox Div., Pittsburgh, Pa.

Forest Biology Symposium

Registration forms are now available from TAPPI headquarters for the Forest Biology Symposium, to be held at the New Washington Hotel, Seattle, Wash., Aug. 24–26, 1960.

The symposium is sponsored by the TAPPI Forest Biology Committee, D. D. Stevenson, The Buckeye Cellulose Corp., Foley, Fla., chairman. R. J. Seidl, Simpson Timber Co., Seattle, Wash., is general chairman of the 3-day meeting, and J. W. Duffield, W. B. Greeley Forest Nursery, Nisqually, Wash., is technical program chairman. R. Z. Callaham, U. S. Forest Service, Spokane, Wash., is local arrangements chairman.

Requests for registration forms and further information should be addressed to TAPPI, 360 Lexington Ave., New York, N. Y.

Eleventh Testing Conference

The Eleventh Annual Testing Conference sponsored by the Technical Association of the Pulp and Paper Industry will be held September 27th through 29th, 1960, at the Pantlind Hotel, Grand Rapids, Mich.

C. E. Jakeway, American Box Board Co., Grand Rapids, Mich., is local arrangements chairman for the conference, which will include four, half-day technical sessions as well as meetings of all committees of the TAPPI Testing Division.

W. R. Willets, Titanium Pigment Corp., New York, N. Y., is in charge of the technical program, which will feature a symposium on relative humidity jointly sponsored by ASTM Committee D-6 and the TAPPI Testing Division.

W. H. Aiken, Personal Products Corp., Mill Town, N. J., is general chairman of the meeting, which is held annually by the TAPPI Testing Division.

Hotel reservations should be addressed to TAPPI Testing Conference, Pantlind Hotel, Grand Rapids, Mich.

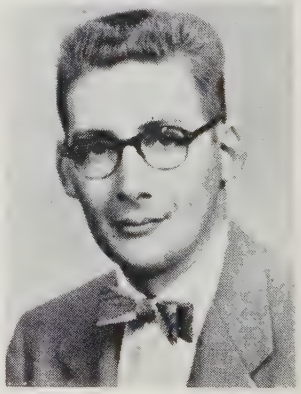
Fifteenth Plastics—Paper Conference

The fifteenth TAPPI Plastics-Paper Conference will be held at the Hotel Syracuse, Syracuse, N. Y., Oct. 17 to 19, 1960, under the general chairmanship of V. T. Stannett, New York State College of Forestry, Syracuse, N. Y.

The three-day technical program is being planned by a subcommittee under the chairmanship of R. W. Loheed, Chas. T. Main, Inc., Boston, Mass. Five, half-day technical sessions are scheduled as follows:

1. Wet Strength and Interfiber Bonding Session, K. W. Britt, Scott Paper Co., Chester, Pa., *chairman.*
2. General Plastics-Paper Session, W. N. Stickel, Texon, Inc., South Hadley Falls, Mass., *chairman.*

W. R. Willets, program chairman, 11th Testing Conference



R. W. Loheed, program chairman, 15th Plastics Paper Conference

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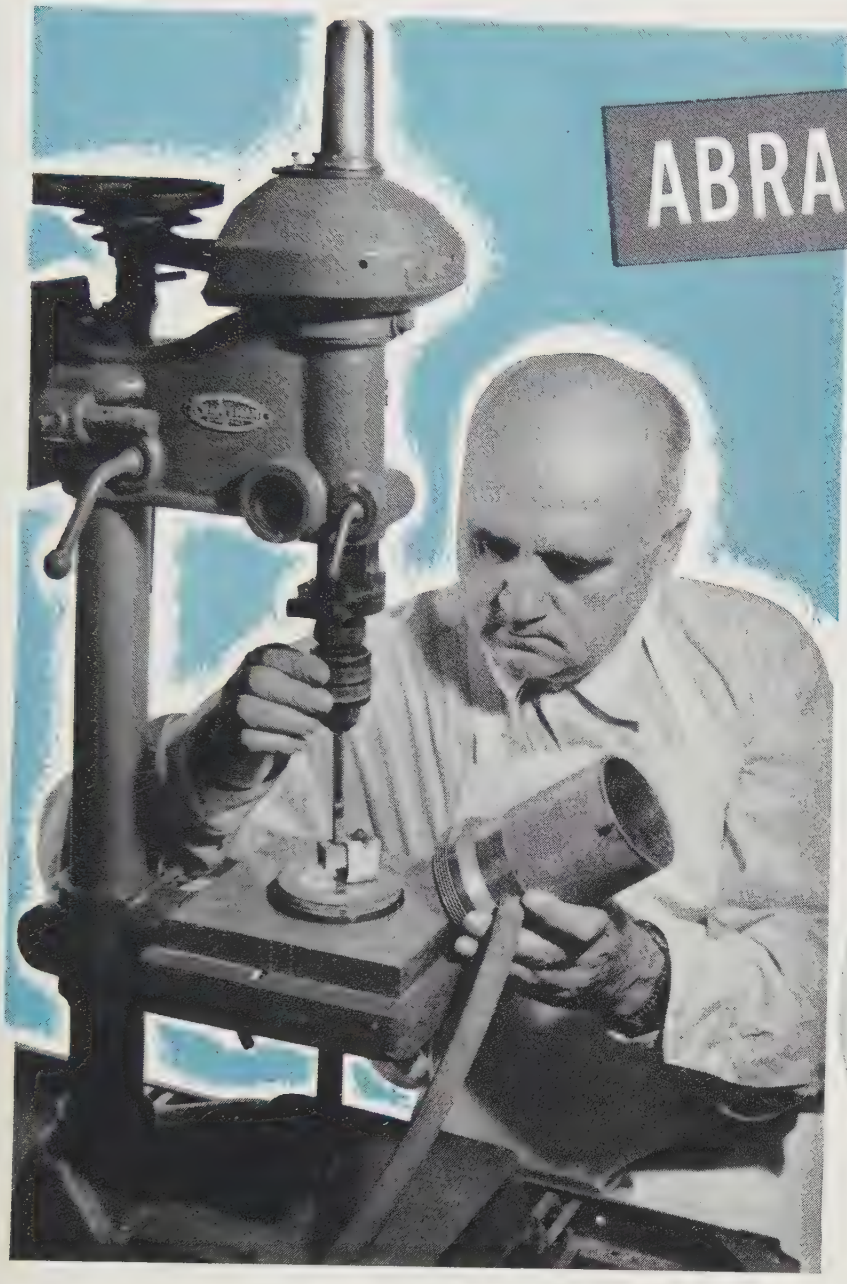

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3. Plastics Coating Session, G. L. Booth, Dilts Div., Black-Clawson Co., Fulton, N. Y., *chairman.*
4. Plastics Laminates Session, H. A. Spencer, Knowlton Bros., Watertown, N. Y., *chairman.*
5. Synthetic Fiber Paper Session, T. A. Howells, The Institute of Paper Chemistry, Appleton, Wis., *chairman.*

In addition, the annual banquet will feature as guest speaker Dr. Donald H. Davenport, Deputy Commissioner of Commerce of New York State.

One-half day of the conference will be devoted to visiting laboratories and plants in the Syracuse area.

Hotel reservations should be addressed to TAPPI Plastics Paper Conference, Hotel Syracuse, Syracuse, N. Y.

Ninth Statistics Course

Application forms are now available for the 9th Pulp and Paper Statistics Course, to be held at Brevard College, Brevard, N. C., Aug. 8 to 19, 1960. Requests for forms should be addressed to Dr. R. J. Hader, The Institute of Statistics, North Carolina State College, Raleigh, N. C. Attendance is limited and applications are accepted in the order received.

The fee for either the basic or the advanced section of the course is $275, covering board and room for the two-week period, textbook, and other materials.

Basic Section

This section of the course will cover the basic concepts of statistics in a series of 18 lectures and a like number of laboratory sessions based on practical examples from the pulp and paper industry. Little or no previous acquaintance with statistics will be assumed, and the level of presentation will be fairly elementary. The text used will be O. L. Davies' "Statistical Methods in Research and Production" (3rd Edition).

Topics to be covered include:

1. Concepts of random variation and its quantitative description.
2. Sampling variation in means and standard deviations.
3. Sampling variation in the difference between two means and in the ratio of two standard deviations.
4. Confidence limits and significance testing.
5. Introduction to analysis of variance.
6. Basic principles of quality control.
7. Fitting of straight lines by least squares.
8. Fitting of polynomials and equations with several variables.
9. Introduction to response surface methodology.
10. Introduction to design of experiments including randomized blocks, latin squares, and simple factorials.

Advanced Section

This section is intended for people who already have an understanding and some experience in application of the basic section topics. A series of coordinated lectures will be given on each of several somewhat more advanced topics. Laboratory practice and discussion sessions are also planned. Opportunity will be available for students to discuss statistical problems of their own with the instructors and with the group.

Topics to be covered in the advanced section include:

1. Multiple regression analysis.
2. Response surface methodology.
3. Experimental design and analysis of variance.
4. Variance components.
5. Linear programming.

Staff

The staff will be made up of three statisticians from industry and two from the Institute of Statistics at North Carolina State College. All have had many years of experience in teaching and in practical applications of statistics.

A. H. E. Grandage, Institute of Statistics, N. C. State College
R. J. Hader, Institute of Statistics, N. C. State College
Carl E. Noble, Kimberly Clark Corp., Neenah, Wis.
Allan E. Paull, Abitibi Power and Paper Co., Ltd., Toronto, Ont.
M. S. Renner, Dewey and Almy Chemical Co., Cambridge, Mass.

This course is jointly sponsored by the Technical Section, Canadian Pulp and Paper Association, and the Technical Association of the Pulp and Paper Industry, and will be conducted by the Institute of Statistics, North Carolina State College.

Pulp Bleaching Conference

One of the features of the Pulp Bleaching Conference to be held at Chicago's Edgewater Beach Hotel, June 14–16, 1960, will be a panel discussion, "Progress in Pulp Bleaching."

This discussion will be moderated by R. P. Whitney, The Institute of Paper Chemistry, Appleton, Wis. The panel is comprised of:

H. W. Giertz, The Technical University of Norway, Trondheim, Norway
N. Hartler, Swedish Forest Products Research Laboratory, Stockholm, Sweden
W. H. Rapson, The University of Toronto, Toronto, Ont.
R. J. Stevens, Canadian International Paper Co., Montreal, Que.
J. A. Van den Akker, The Institute of Paper Chemistry, Appleton, Wis.

This panel of internationally known authorities on pulp bleaching will consider timely questions such as:

"Where do we stand today in pulp bleaching? Are we doing an adequate job? Are we progressing toward better performance? Is our rate of progress satisfactory? What are the 'roadblocks' to further progress? What are we doing about these roadblocks?

"Is our research and development geared too much to present-day technology and presently employed bleaching agents? What problems in bleaching and purification will be posed by new developments in other areas of pulp and paper technology? Do we have an understanding of the mechanisms of bleaching which is adequate to predict performance with new pulps to yield new products? Are we adequately concerned with audacious thinking regarding entirely new approaches to bleaching?"

H. L. Crosby, Dorr Oliver, Inc., Stamford, Conn., has been named moderator of an additional Technical Session, occurring on Wednesday evening, June 15, 1960.

Another paper, "Deresination of Sulfite Pulp with Nonionic Surfactants," by J. W. Wilson, D. Omeara, and R. M. Patteron (Note—not Patterson), Columbia Cellulose Co., Ltd., Prince Rupert, B. C.

R. J. Auchter, Kimberly Clark Corp., Neenah, Wis., is technical program chairman and F. Kraft, Marathon Division, American Can Co., Menasha, Wis., is general conference chairman.

Those who are interested in attending the conference may secure hotel reservations by writing to "TAPPI Pulp Bleaching Conference, Edgewater Beach Hotel, Chicago 40, Ill."

Should further information about the conference be desired, please write H. O. Teeple, TAPPI, 360 Lexington Ave., New York 17, N. Y.

Ninth
Satistics Course
North Carolina State College
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Aug. 8–12, 1960

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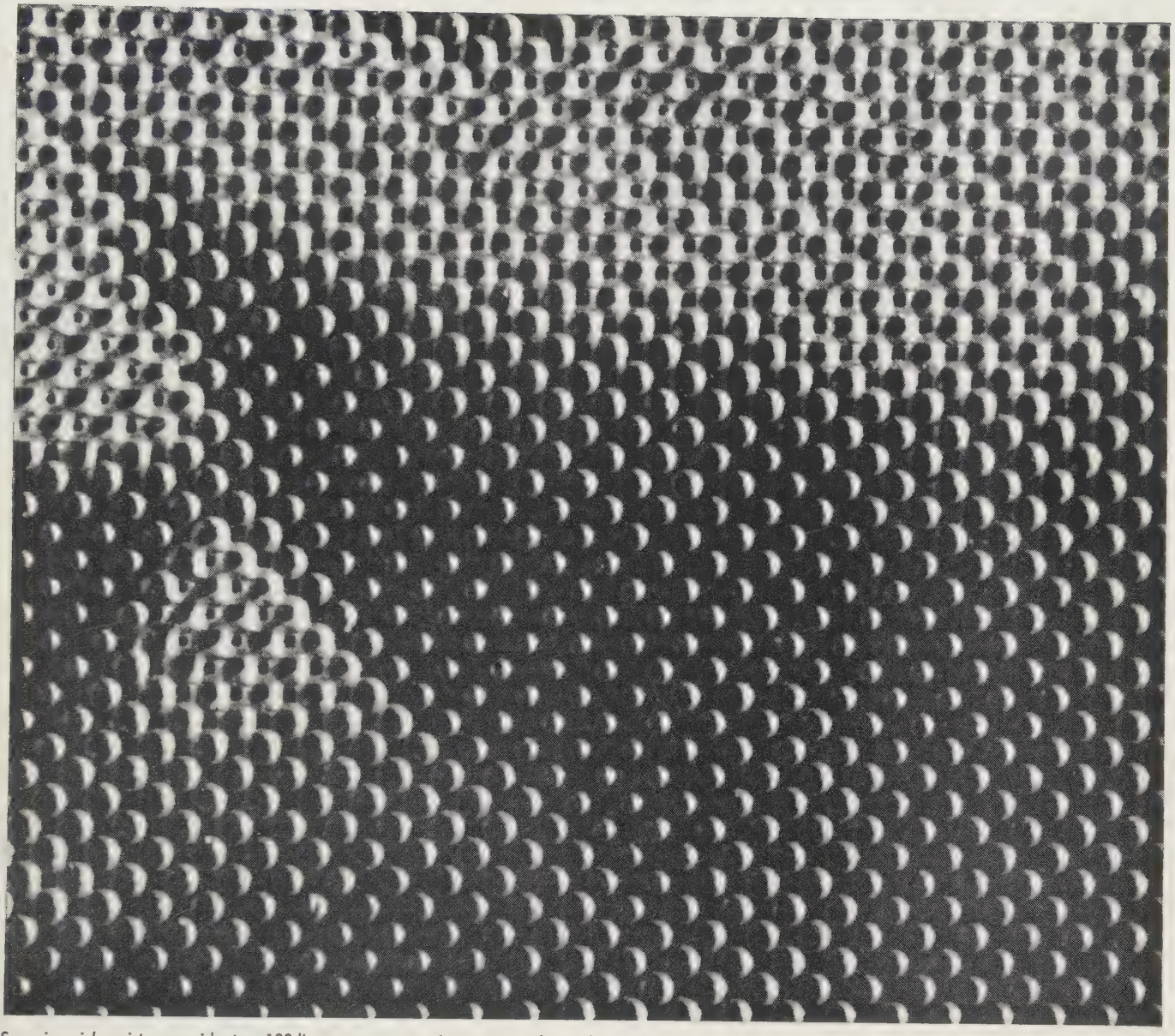

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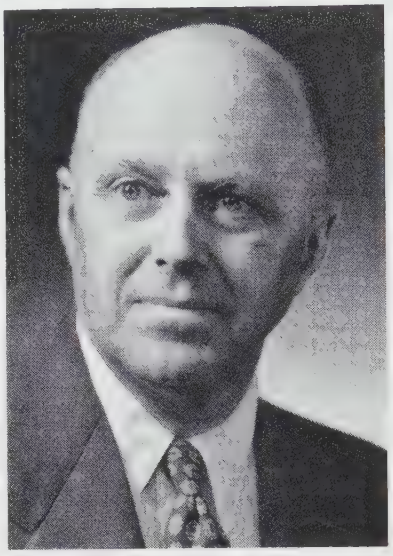

John L. Parsons

John L. Parsons, consultant to the paper industry, has been a member of TAPPI for 36 years and chairman of the Projects Appropriations Committee for the last 25 years. Charged with the responsibility of considering applications for funds to finance TAPPI committee projects, the Project Appropriations Committee, since its creation, has made 142 grants totaling more than half a million dollars. By education and experience John Parsons has been well qualified to head this committee for a quarter of a century, concurrently with his activities on other TAPPI committees, ACS divisions, and teaching and writing assignments.

Born in Rye, N. H., he attended Portsmouth High School and Phillips Exeter Academy before obtaining a B.S. in chemistry from the Massachusetts Institute of Technology. After having spent one year on the staff of MIT, he went to Boston University for 3 years as instructor in chemistry, and in 1920 was placed in charge of the summer session in chemistry. In 1923 a Hammermill Paper Co. Fellowship in cellulose chemistry sent him to Yale University, where he studied under Professor Harold Hibbert, and from which he graduated in 1925 with a Ph.D. degree.

John Parsons first came into contact with the paper industry in 1920. In that year he joined the Hammermill Paper Co., Erie, Pa., as a research chemist, later to become chief of its research department. In 1945 he became director of research for the Hollingsworth and Whitney Co., Waterville, Me., and subsequently technical director of its northern mills. In 1952 he joined the staff of Foster D. Snell, Inc., New York, for a 3-year period, and in 1957 went with Calkin and Bayley, Inc., New York, as vice-president in charge of pulp and paper.

The present Project Appropriations Committee was created in 1935 as the Committee on Educational Cooperation. It became the Research Appropriations Committee before being known by its present name. A former member of the Executive Committee, the Committee on Abstracts and Bibliography, and of the Editorial Board of *Tappi*, John Parsons is a past chairman of: the Cellulose Committee and of the Raw Materials Division (1930), which supplanted the former committee; the Color Committee, which was subsequently reorganized to form the Optical Properties Committee; the Maine-New Hampshire Section of TAPPI; the Instrumentation Committee of the American Paper and Pulp Association (5 years); the Mechanical Pulping Committee and general chairman of the First International Mechanical Pulping Conference in 1948 at Poland Spring, Me., co-sponsored by TAPPI and the Technical Section of the Canadian Pulp and Paper Association.

In 1940 he organized a symposium on spectrophotometry for the pulp and paper industry, and for many years was a voting delegate for TAPPI on the Inter-Society Council, and a member of its board of directors and participant in its committee on color aptitude tests.

John Parsons has been a member of the American Chemical Society since 1918. A member of the ACS Alpha-Cellulose Test Committee, he is past secretary and chairman of its Division of Cellulose Chemistry, past chairman of the Erie and Maine Sections of the ACS, and a former councillor-at-large of the Society. Formerly he was active in the ACS radio broadcasting program in Pennsylvania and Maine.

He is the author of many articles on the oxidation of cellulose, bleaching, alpha-cellulose, viscosity of cellulose, paper and packaging, and of the chapters on the sulfite process, pulp bleaching, and the machine room in "Modern Pulp and Paper Making," by John Calkin. He is also a contributor to *Packaging Serves the Nation* (American Management Association), and author of the sections on *paper* in the "Encyclopedia Americana," and on *packaging* in the "Encyclopedia Britannica." For several years he was an abstracter of pulp and paper periodicals for *Chemical Abstracts*, and a lecturer on bleaching, paper, and related subjects at the University of Maine, Allegheny College, and Colby College.

John Parsons is a Fellow of the American Association for the Advancement of Science and the Institute of Chemists, member of the Technical Section of the Canadian Pulp and Paper Association, the Society of the Sigma Xi, Alpha Chi Sigma, Portsmouth (N. H.) Rotary Club, Chemists' Club of New York, and the National Rifle Association. He is the father of three children, one of whom is in the paper industry. Formerly on the official board of the Pleasant Street Methodist Church, Waterville, Me., he is presently a member of the Rye Congregational Church, chairman of its Building Committee, and author of "The Churches of Rye, New Hampshire." He is a former council commissioner of the Washington Trail and the Pine Tree Councils of the Boy Scouts of America, and a member of its National Council. A 20-year veteran of the BSA, he is a member of the Order of the Arrow and holds the Silver Beaver Award. He is associated with the Daniel Webster Council, BSA, as district leadership chairman.

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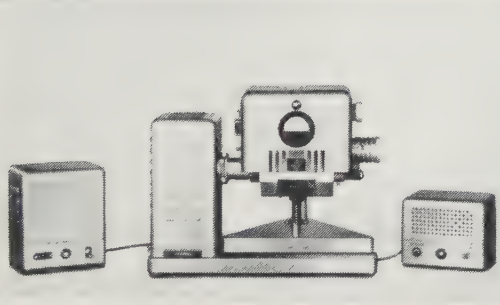

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In measuring the diffused reflectance of surfaces, the instrument selects the wave length by a set of 7 pairs of special narrow band filters.

Special tristimulus filters, also available, are so designed that the tristimulus values for standard illumination C may be directly derived from the measurements.

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The Elrepho is a solidly built instrument that is very easy to operate and can be used with house current—no batteries required. . .High accuracy of 0.1%; reproducibility of 0.3%.

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TAPPI NOTES

Presidents Address—1960

Article I, Section 1, of the bylaws of TAPPI states that: "At the annual meeting the president shall present an address discussing such subjects as are of value to the association."

It is particularly desirable at this time for reports of our progress to be presented to our members. I am sure few people realize the tremendous growth taking place in our association as the technical problems of the industry we represent multiply almost daily.

TAPPI is rapidly becoming one of the largest organizations of its kind in the *world*—not just in the United States. At the close of 1959, we had over 10,100 members, including 480 corporate and sustaining members—and approximately 25% of these lived and worked outside of our country.

Your officers and executive committee are well aware of the problems which accompany rapid growth, and our efforts during the past year have been aimed at the improvement of facilities and the expansion of services to our members. Services must keep pace with needs, or there will be no justification for continued existence as a technical association.

One of the principal objectives of your officers, a year ago, was to stimulate the interest of young men in college in the professional opportunities of our entire paper industry.

Just recently, division, committee, and local section officers, along with all corporate and sustaining members, have received a copy of our new publication: "What You Should Know About Career Opportunities Offered by The Pulp & Paper Industry." This represents an outstanding editorial accomplishment, and we have already had glowing national publicity and requests for thousands of copies for distribution.

The preparation of a book of paper industry chemical engineering problems, which will ultimately serve as a supplemental textbook in many engineering schools throughout the country, is now in progress.

There already has been issued an interim publication of the TAPPI College Textbook of Pulping and Papermaking Technology, which is being used in several paper schools.

Along with this, during 1959, talks were presented by TAPPI members to student groups at over 50 colleges and universities. The local sections were particularly helpful in this area.

In February, 1959, TAPPI collaborated with the APPA in sponsorship of a Research Forum during Paper Week. Later, in October, the TAPPI-APPA Research Conference was held in Chicago, with approximately 75 selected industry and educational leaders in attendance.

A year ago, President Ward Harrison appointed a committee to review TAPPI research policy and to formulate a program which would *realistically* serve the best interest of individual TAPPI members and the pulp and paper industry, within the physical limitations of the organization.

With the usual enthusiasm, which is so characteristic of most TAPPI committees, this group worked so rapidly that by the time of the September meeting of our Executive Committee they were prepared to recommend an immediate "short range" program, designed particularly to accelerate project activities of the TAPPI divisions and committees—not only in the development of basic and fundamental information, but also in applied technology.

The committee recommended the implementation of this program to the fullest extent of our financial abilities. The dues of corporate and sustaining members will be used for this purpose.

At the same time, a long range program of basic and applied research was recommended for further study by a TAPPI Research and Advisory Committee, which is to be appointed by your president.

The Executive Committee approved the implementation of the complete report, and I would like to express the appreciation of the entire association to J. R. Curtis, chairman, and J. H. Heuer, F. S. Klein, and J L. Parsons who also served on the committee, for an outstanding contribution to TAPPI.

Our association publication *Tappi* has grown and improved in the past year. Under the leadership of R. G. Macdonald, as editorial director, and with guidance from our secretary-treasurer Phil Nethercut, the publication dates have been stabilized, advertising income has been increased, advertising rates have been made more realistic, the table of contents has been expanded, and new features—such as "TAPPI Notes," the "Engineering Division Question-and-Answer Section," and "TAPPI Profiles" have been added.

An additional man, Michael Kouris, has been added to the staff as assistant editor, to relieve Dick Bingham of many of the editorial duties which must be handled each month.

Since the advertising income of the magazine is directly related to our ability to provide services to our members, we are conscious of the need to keep *Tappi* an outstanding publication.

The continually increasing level of activities of division committees and local sections certainly presents a constant challenge to your officers and staff. In 1959, there were nine large conferences sponsored by the various divisions of TAPPI; and dozens of local section meetings.

Besides this, over 200 committee meetings took place at various locations throughout the entire country.

Whenever possible, your officers and executive committee have been represented at conferences and meetings. Members of our staff have participated to an

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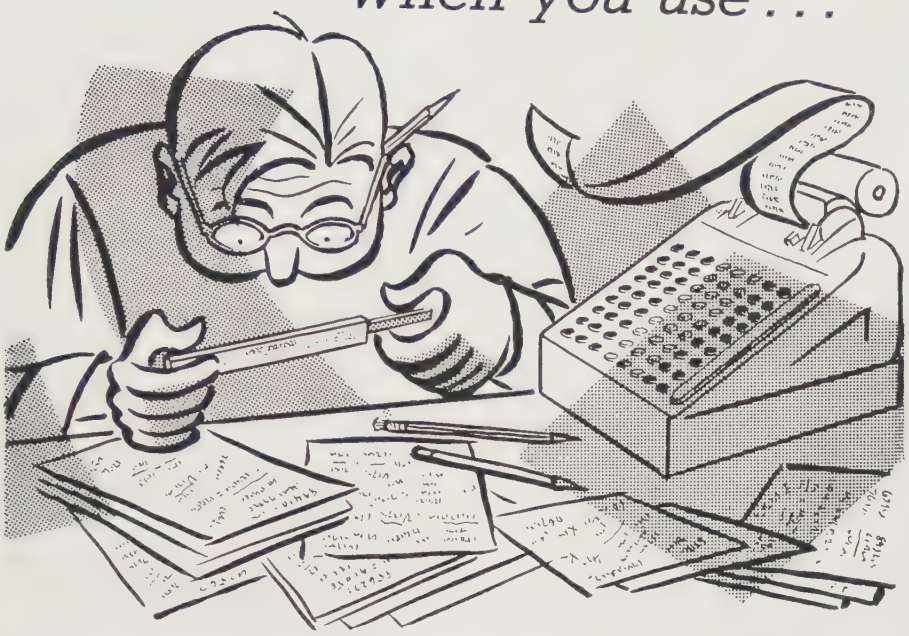

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even greater extent in the planning and organization of these activities.

It was particularly gratifying this year to welcome two new local sections to TAPPI.

The Gulf Coast Section, which originally organized as a district of the Southeastern Section, was chartered in May.

Later, in October, the new Italian Section was chartered, and for the first time our association was officially represented by a chartered group outside the United States.

Plans are already under way to recognize the new St. Louis Section in April, 1960; and the Golden Gate Section, at San Francisco, later in the year.

The charter presentations to both the Gulf Coast and Italian Sections were made by R. G. Macdonald, representing your officers in his capacity as assistant to the president.

Even with all the expansion of our activities during the year, we were able to operate without a deficit for the first time since 1956. Actually, we had a surplus of about $63,000, compared to a total deficit of $122,000 the previous two years.

In view of the fact that we expanded staff, office facilities, and member services all at increased cost, we were very happy with the results achieved in the financial area.

Our expenditures this year will be approximately $800,000 and we fully expect to live within our income.

Along with this, of course, we have a substantial invested reserve to take care of unexpected fluctuations in either our income or our expenditures.

Currently, the income from these investments is helping to pay operating expenses. In addition, this year, we have established a policy of investing any short term surplus, to further supplement our operating income.

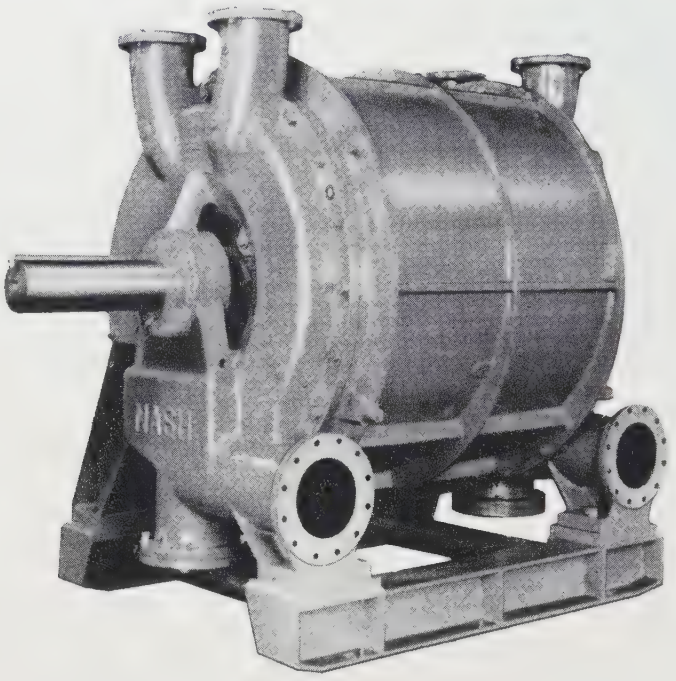
Our capable staff is at full strength for the first time in my experience. In addition, we have provided comfortable office facilities for every person, in an expanded headquarters. Those of you who have not already visited the 17th floor of 360 Lexington Avenue are cordially invited to do so.

Under the direction of Phil Nethercut, our executive secretary, the assignments of both the professional staff and office group have been carefully reviewed to streamline our efforts.

NASH

Paper Mill Vacuum Pumps Designed for Every Desirable Quality, and the First of these is

DEPENDABILITY



When just 3 days lost production on a paper machine can cost more than the vacuum pumps, dependability is the vital factor in pump selection.

Nash Vacuum Pumps are dependable because they are built big enough and heavy enough to stand the pounding of around the clock production, day in and day out. They are reliable because they have only one moving part, and that rotating without wearing metallic contact. They are reliable because the heavy duty ball bearings are located outside the pump casing where they are accessible. They are reliable because they operate at the low speeds necessary for long life and reliable operation.

Nash Vacuum Pumps have been proving their ability to insure uninterrupted production in leading paper mills for nearly a half century. Install them and be safe.

The new Nash 5308-A shown above, has four separate suction inlets, each of which functions independently of the others. This offers the machine operator great flexibility, since these may be used in any desired combination to produce a variety of capacities and vacuums.

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Because of the tremendous importance of our editorial activities, we have asked R. G. Macdonald, who has served this past year as assistant to the president, to concentrate his efforts practically full time on our publication activities and policies, as editorial director. At the meeting of the Executive Committee yesterday he was elected treasurer of the Association.

Working with Mac, we have assigned Dick Bingham, as editor of *Tappi*, and Mike Kouris, as assistant editor.

We have assigned A. J. Winchester, Herb Teeple, and Maury Bernston, to be responsible for the direction of all the activities and programs of the various divisions and committees. At the same time, Jim Field has been working full time on local section activities.

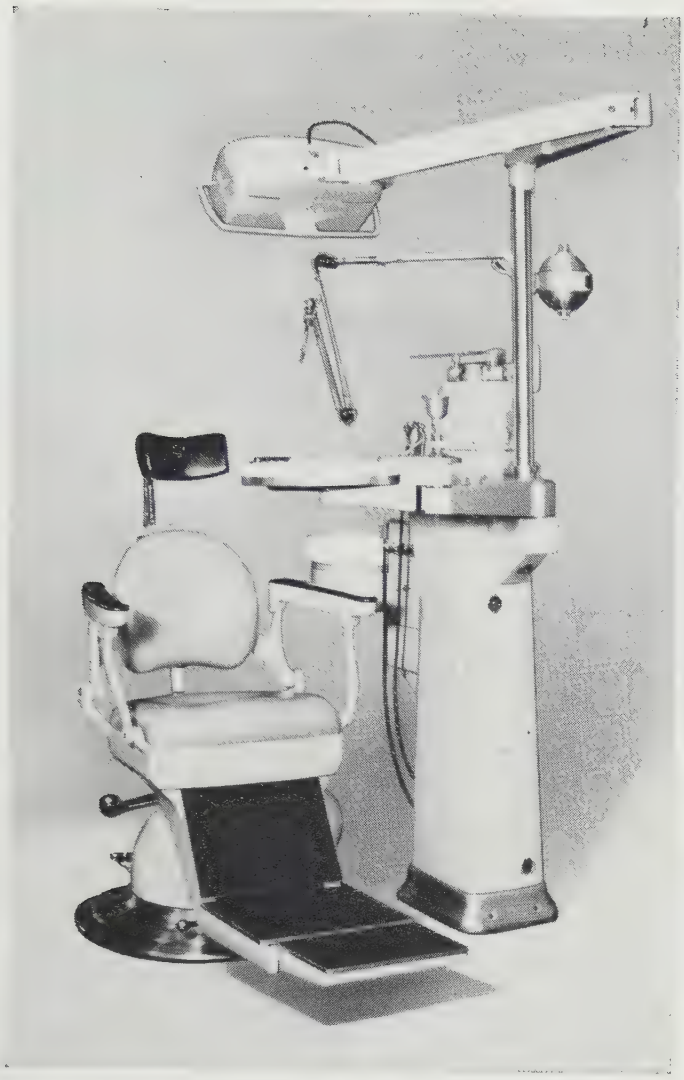
All of these men are well qualified and fully trained to carry out their designated responsibilities. In short, we have a well-organized, hard working team, of which we can all be proud. Certainly, all of them cooperated with me to the fullest this year, and their efforts and accomplishments are deeply appreciated.

The year 1960—and, in fact, the next decade, promises to be an interesting one for TAPPI and its members. Our industry has expanded rapidly and will continue to grow. However, in the face of ever increasing competition for our markets, rising raw material expenditures, and higher labor costs, there is a tremendous challenge to the technically trained men of our industry to contribute more and more to the profitability of our operations.

If the Technical Association of the Pulp and Paper Industry is to continue its current growth pattern, it must, more than ever before, do a thorough job of collecting and disseminating information and promoting the investigation and interchange of ideas among its members. Your officers are dedicated to this objective during the coming year.

In closing, I would like to express my deep personal appreciation for the privilege of having served as president of TAPPI in 1959. It has been an inspiring and stimulating experience, the memories of which I will always cherish.

JAMES R. LIENTZ



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These two chairs show what a vast difference a change of purpose can make. One is designed for comfort, the other for convenience . . . they're as far apart as pleasure and pain.

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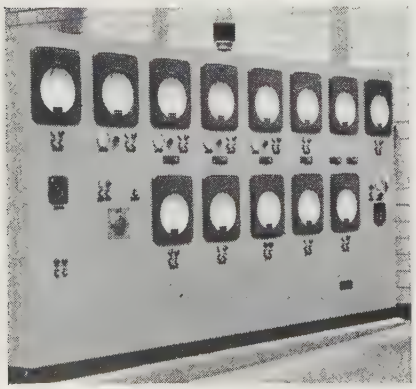
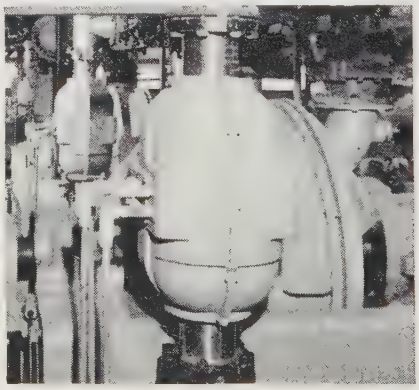
Pulp stocks, chemicals,
no liquid is too tough for the

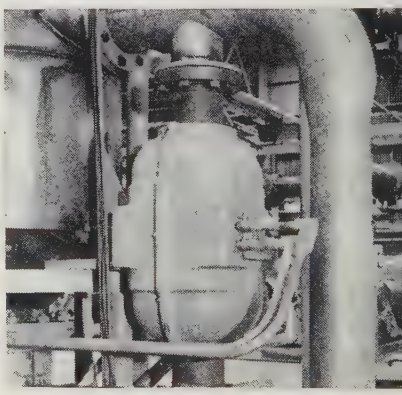
Crown-Zellerbach Antioch, Calif. uses Foxboro Magnetic Meters for blending fir and hemlock stocks. Rugged meters are installed outdoors — need no protective housing.



Foxboro Dynalog recorders give operators continuous chart records of the Magnetic Meters linear output. Like the flow meter, Dynalog recorders seldom require maintenance.



St. Regis Paper Company, Jacksonville, Florida. St. Regis uses 5 Foxboro Magnetic Flow Meters in its stock refining system. Meters are 6″ in diameter. System was installed in 1956.



Riegel Paper Corporatio Acme, North Carolina. Riegel has seve Magnetic Meters in its mill. The 8″ me shown above measures broke flow in th pulp stock blending control system.

additives, dyes...
Foxboro Magnetic Flow Meter

hundreds of successful installations reported by America's leading mills

Introduced six years ago, the Foxboro Magnetic Flow Meter has proved its superiority for measuring the toughest pulp and paper mill liquids. Pulp stocks, mud slurries, starch, liquors all flow right through the meter without plugging up.

That's because the Magnetic Meter has no flow restrictions of any type. No taps to get plugged or frozen, no seals or purges, no moving parts of any kind. Measurement is made by electrodes flush-mounted in corrosion-proof meter wall — then transmitted by electric cable to a Foxboro Dynalog* electronic recorder. System accuracy is ±1%.

Foxboro Magnetic Flow Meters have solved some of the paper industry's toughest measurement problems. Ask your Foxboro field engineer to show how it can help with yours. Or write for Bulletin 20-14. The Foxboro Company, 305 Norfolk St., Foxboro, Mass.

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FOXBORO

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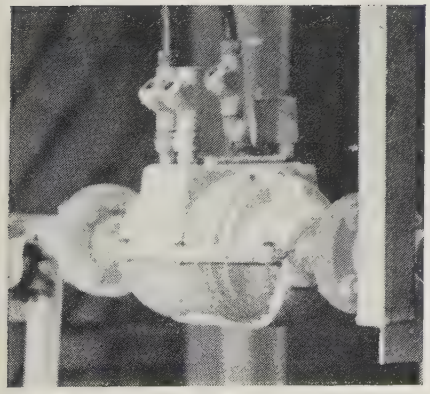
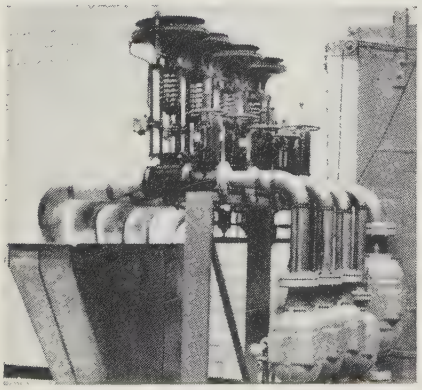
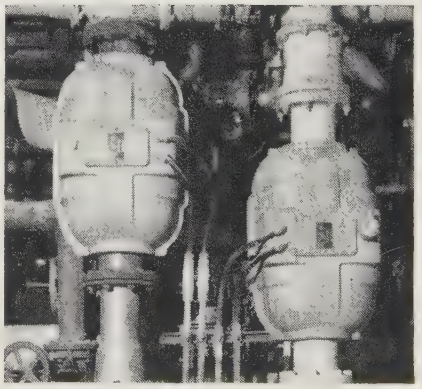


Gulf States Paper Corporation, Demopolis, Ala. Gulf States uses this 2″ Magnetic Meter to measure chlorine dioxide flow. This highly corrosive chemical has no effect whatever on the Magnetic Meter.



International Paper Company, Corinth, New York. At International Paper, Foxboro Magnetic Meters allow one operator at a central panel to blend 5 pulp stocks — as well as additives and dyes — accurately and continuously.



Scott Paper Company, Chester, Pa. Scott has a total of 9 Foxboro Magnetic Flow Meters. The first installed on a bleach line over 6 years ago, has required maintenance only once — a new vacuum tube for its Dynalog recorder.

PERSONAL MENTION

New TAPPI Members

Mehmet H. Akdeniz, Manager, Sugar Factory Adana, Turkiye Seker Fabrikalari, A. S., Ankara, Turkey.

Karekin G. Arabian, Senior Chemist, Shell Oil Co., Houston, Tex., a 1937 graduate of Massachusetts Institute of Technology.

Andrew D. Armstrong, Pulping Development Group Supervisor, St. Regis Paper Co., Deferiet, N. Y., a 1951 graduate of McGill University.

Mary E. Baker, Librarian, Minnesota Mining and Manufacturing Co., St. Paul, Minn.

Dennis R. Barbour, Director, Easton & Johnson Ltd., Taunton, Somerset, England. Attended Bolton Technical College.

Donald S. Batchelor, Technical Service Engineer, Solvay Process Div., Allied Chemical Corp., Syracuse, N. Y. Attended Syracuse University.

Herman J. Bayer, Technical Superintendent, St. Regis Paper Co., Bucksport, Me., a 1950 graduate of University of Maine.

James N. Beyer, Technical Service Representative, E. I. du Pont de Nemours & Co., Cleveland, Ohio, a 1944 graduate of University of Wisconsin.

Paul W. Blanchard, Research Librarian, Addressograph-Multigraph Corp., Cleveland, Ohio.

John Blood, Jr., Technical Planner, St. Regis Paper Co., New York, N. Y., a 1955 graduate of University of Pennsylvania.

Edgar Bluhm S., Laboratory Chief, Universidad de Concepcion, Concepcion, Chile, a 1957 graduate of Chemical Engineering School.

Lloyd O. Boots, Technical Assistant, Simpson Paper Co., Lowell, Wash., a 1953 graduate of University of Puget Sound.

Richard A. Boss, Technical Director, Personal Products Corp., Milltown, N. J., a 1950 graduate of Middlebury College.

A. Boussion, Librarian, Centre de Documentation du Centre National de la Recherche Scientifique, Paris, France.

Thomas R. Bowdren, Sales Engineer, Metal Cladding, Inc., North Tonawanda, N. Y.

Eugene W. Brass, Manager, Technical Sales, Buffalo Tank Div., Bethlehem Steel Co., Dunnellen, N. J., a 1929 graduate of Cooper Union.

Harry A. Brown, Assistant Superintendent, Board Machines, Weyerhaeuser Co., Longview, Wash. Attended University of Portland.

John C. Brown, Jr., Sales Engineer, Improved Machinery Corp., Nashua, N. H., a 1949 graduate of Rensselaer Polytechnic Institute.

Hugh R. Bryson, Paper Chemist, Formica Limited, Northumberland, England, a 1956 graduate of Glasgow University.

Victor W. Carver, Sales Engineer, Waldron-Hartig Div., Midland-Ross Corp., New Brunswick, N. J., a 1953 graduate of Hackney Technical University.

James J. Casserly, Sales Manager, Textile Paper Div., Wollerstein Co., Staten Island, N. Y., a 1942 graduate of Clemson College.

Peter J. Child, Assistant General Manager, Alex. Pierie & Sons, Ltd., Aberdeen, Scotland, a 1948 graduate of Trinity College, Cambridge, England.

M. A. Costello, Technical Information Secretary, Picatinny Arsenal, Dover, N. J.

James J. Curry, Design Draftsman, Roderick O'Donoghue & Co., New York, N. Y., a 1936 graduate of St. Peter's College.

Antonio Da Silva, Chemical Engineer, Brunswick, Ga., a 1953 graduate of Newark College of Engineering.

Hazel C. Davis, Librarian, The National Plastic Products Co., Odenton, Md.

Marcus H. Davis, Assistant Supervisor, Plastics and Coal Chemical Div., Allied Chemical Corp., a 1953 graduate of Bowling Green State University.

Sergio De Carolis, Information Officer, Edisonvolta S.p.A., Milano, Italy, a 1935 graduate of Roma University.

Donald B. Dik, Supervisor, Chemical Industry Marketing, Titanium Metals Corp. of America, New York N. Y., a 1949 graduate of Tufts University.

Karl A. Dix, Technical Problems Engineer, Kimberly-Clark Corp., Niagara, Wis., a 1953 graduate of Purdue University.

Paul A. Donaghy, Jr., Sales, Corn Products Co., Greensboro, N. C., a 1949 graduate of New Bedford Textile Institute.

Karl Dornish, Jr., Technical Service Engineer, S. D. Warren Co., Cumberland Mills, Me., a 1954 graduate of Colby College.

Thomas A. Downey, Technical Representative, Chas. Pfizer Co., Inc., Brooklyn, N. Y., a 1953 graduate of Polytechnic Institute of Brooklyn.

Hal C. Felsher, Director, Research and Development, Claremont Pigment Dispersion Corp., Roslyn Heights, L. I., N. Y., a 1945 graduate of Polytechnic Institute of Brooklyn.

Charles F. Fitzpatrick, Service Supply Supervisor, Friden, Inc., Rochester, N. Y.

Richard P. Fox, Assistant to Pulp Mill Superintendent, St. Regis Paper Co., Tacoma, Wash., a 1940 graduate of University of Colorado.

John McD. Fultz, Director of Sales Development, Reynolds Metal Co., Richmond, Va., a 1938 graduate of Virginia Polytechnic Institute.

Gilbert G. Garner, Student, North Carolina State College, Raleigh, N. C.

Giorgio Gianoli, Research Manager, Arnoldo Mondadori Editore, Verona, Italy. Attended London School of Printing.

James L. Gleim, Salesman, American Cyanamid Co., New York, N. Y., a 1958 graduate of Rider College.

Karl O. Glifberg, Chief Project and Sales Engineer, Leckners Verkstads AB, Jonkoping, Sweden.

Dorothy L. Godshalk, Technical Control Analyst, Dixie Cup Div., American Can Co., Easton, Pa. Attending Muhlenberg College.

Gene R. Goehringer, Manager, Vacuum Pump Sales, Roots-Connersville Blower Div., Connersville, Ind., a 1949 graduate of Purdue University.

Robert F. Goodwin, Research & Development Chemist, American Sisalkraft Corp., Attleboro, Mass., a 1951 graduate of Rhode Island School of Design.

Paul Gora, Vice-President and General Manager, Pulp and Paper Div., Beaco, Ltd., Montreal, Que., Canada, a 1938 graduate of State Technical College, Poland.

Lyle J. Gordon, Research and Development Manager, Scott Paper Co., Everett, Wash. Attended University of Washington.

William R. Groff, Project Engineer, Federal Paper Board Co., Inc., Bogota, N. J., a 1949 graduate of Columbia University School of Engineering.

Louis P. Growney, Industrial Development Engineer,

Pacific Power & Light Co., Portland, Ore., a 1943 graduate of University of Alabama.

R. S. Gupta, Shift Manager, Soda Recovery Plant, West Coast Paper Mills, Ltd., Bangur Nagar, Mysore State, India.

Uriel W. Ham, Vice-President, Engineering, Triangle Container Corp., Chicago, Ill., a 1950 graduate of University of Michigan.

Ralph Harris, Research Foreman, Champion Paper & Fibre Co., Hamilton, Ohio.

Charles A. Heiberger, Assistant Director, Air Reduction Co., Inc., Murray Hill, N. J., a 1935 graduate of Lehigh University with a Ph.D. degree in 1939.

Hans O. Heijne, Paper Mill Superintendent, Munksjo A. B., Jonkoping, Sweden, a 1955 graduate of Royal Institute of Technology.

Thomas A. Hewson, Director of Technical Planning, St. Regis Paper Co., New York, N. Y., a 1945 graduate of Massachusetts Institute of Technology.

Max Holl, Superintendent, G. Haindlsche Papierfabriken, Schongau, Lech, Germany, a 1937 graduate of Technische Hochschule Darmstadt, with a Dr.Ing. degree.

C. Wayne Holley, Research Engineer, Combustion Engineering, Inc., Chattanooga, Tenn., a 1955 graduate of University of Chattanooga.

Frank P. Hughes, Technical Director, Island Paper Mills Div., MacMillan, Bloedel & Powell River, Ltd., New Westminster, B. C., Canada, a 1948 graduate of London University, London, England.

Gunther Hunger, Scientific Research Assistant, Institute for Cellulose Chemistry, Darmstadt, Germany, a 1954 graduate of the Technical University, Darmstadt, with a D.S.C. degree in 1959.

Robert B. Hurm, Staff Engineer, Beloit Iron Works, Beloit, Wis., a 1948 graduate of Pennsylvania State College.

Isao Iijima, Research Engineer, Paper Making Div., Kumamotoken, Japan, a 1953 graduate of Nagoya University.

Edward Isenberg, Sanitary Microbiologist, Hamilton Paper Co., Miquon, Pa., a 1960 graduate of Rutgers University.

George A. Jaeger, Senior Engineer, Federal Paper Board Co., Inc., Bogota, N. J. Attended Stevens Institute and New York University.

Ralph H. W. James, Technical Superintendent, Columbia Cellulose Co., Ltd., Prince Rupert, B. C., Canada, a 1949 graduate of University of Birmingham, England.

Max Kaiser, Director, Paper Dept., Ministry for Commerce and Industry, Government of Israel, Jerusalem, Israel, a 1933 graduate of Kothen University, Germany.

Karl F. Keirstead, Chief Chemist, Lignosol Chemicals, Ltd., Quebec, P. Q., Canada, a 1949 graduate of Laval University with a DB.Sc. degree.

Harry B. Kellog, Jr., Superintendent, Chemical Engineering Laboratory, Kimberly-Clark Corp., Neenah, Wis., a 1936 graduate of University of Michigan.

Robert J. Keswick, Mill Manager, Bathurst Power & Paper Co., Ltd., Bathurst, N. B., Canada, a 1937 graduate of University of New Brunswick.

Kenneth A. Kuiken, Head, Analytical Methods & Services, Buckeye Cellulose Corp., Memphis, Tenn., a 1939 graduate of Geneva College.

Robert B. Laine, Sales Engineer, Southern Corp., Charleston, S. C.

Charles B. Lawler, Plant Manager, Union Bag-Camp Paper Corp., Trenton, N. J., a 1947 graduate of Georgia Institute of Technology.

Martin A. Leuchtenberger, Dept. Manager, Spaulding Fibre Co., Tonawanda, N. Y., a 1949 graduate of Rensselaer Polytechnic Institute.

Se Keng Lim, General Manager, Keng Hua Paper Product, Inc., Manila, Philippines.

Eric M. Lipman, U. S. Agent, A. R. Heathcote & Co., Ltd., Sheffield, England, a 1932 graduate of University of Geneva, Switzerland.

Charles E. Lowden, Sales Representative, American Cyanamid Co., Pigments Div., New York, N. Y., a 1955 graduate of St. Peter's College.

Frederick A. MacMillan, Physicist, Abitibi Power & Paper Co., Ltd., Central Research Div., Sault Ste. Marie, Ont., Canada, a 1951 graduate of Queen's University.

Ulisse Mannucci, Plant Manager, Cartiere Miliani Fabriano S.p.A., Miliani, Italy, a 1941 graduate of Instituto Industriale.

Paul G. Mansuy, Sales Manager, Huyck Felt Co., Rensselaer, N. Y., a 1948 graduate of Lafayette College.

Giovanni Margaritelli, Wood Industry Manager, Fernando Margaritelli S.N.C., Perugia, Italy.

John E. Maryanski, Supervising Chemist, Paper Section, Corn Products Co., Argo, Ill., a 1957 graduate of University of Notre Dame.

Honor C. McCusker, Director of Library Services, United States Library, Athens, Greece, a 1930 graduate of Brown University with a Ph.D. degree in 1937 from Bryn Mawr College.

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Edward V. McKenna, Sulfiite Superintendent, International Paper Co., Corinth, N. Y., a 1941 graduate of Catholic University.

Hans Meier, Manager, Karnaphuli Paper Mills Ltd., Chandraghona, East Pakistan, a 1937 graduate of Technical University, Darmstadt.

Karl W. Meschke, Associate Director of Research, The Mead Corp., Chillicothe, Ohio, a 1951 graduate of Georgia Institute of Technology.

Arthur L. Minto, Technical Superintendent, Scott Paper Co., Mobile, Ala., a 1942 graduate of University of Alabama.

Nicholas M. Molnar, President, Fine Organics, Inc., Lodi, N. J., a 1926 graduate of Copper Union.

Helio Morganti, Director, Refinadora Paulista S. A., Sao Paulo, Brazil, a 1928 graduate of Colegio Cicognini.

George F. Murray, Research Supervisor, General Cable Corp., Bayone, N. J., a 1938 graduate of Canisius College.

Lawrence E. Murray, Technical Supervisor, Container Corp. of America, Wilmington, Del., a 1958 graduate of University of Delaware.

Masamitsu Nagano, Chief of Rayon Researches, Kurashiki Rayon Co., Ltd., Osaka, Japan, a 1933 graduate of Tokyo University of Technology with a Dr. of Engineering degree.

John L. Neiderer, Chemist, P. H. Glatfelter Co., Spring Grove, Pa., a 1950 graduate of Pennsylvania State University.

Ikuro Norizuki, Chemical Engineer, Matsutani Chemical Co., Ltd., Hyogo-ken, Japan, a 1951 graduate of Tokyo Agricultural College.

Forrest G. Parker, Jr., Sales Engineer, Improved Machinery, Inc., Nashua, N. H., a 1942 graduate of Tufts College.

Irving H. Peters, Manager, Field Service, Huyck Felt Div., Huyck Corp., Rensselaer, N. Y., a 1940 graduate of New York College of Forestry.

William I. Phillips, Jr., Engineering Manager, C & H Supply Co., Seattle, Wash., a 1950 graduate of University of Portland.

Dale W. Quackenbush, Research Associate, Weyerhaeuser Timber Co., Longview, Wash., a 1950 graduate of Kansas State College.

Torsten Ramen, Managing Director, AB Ramens Patenter, Stockholm, Sweden, a 1930 graduate of Tekniska Laroverket, Orebro.

Creed H. Reagan, Chief Industrial Engineer, Union Bag-Camp Paper Corp., Savannah, Ga., a 1944 graduate of University of Tennessee.

Howard R. Rickards, Consultant, Rochester, N. H. Attended Drexel Technical Institute.

Yves E. Rollin, Director of Laboratory, Société Française des Petroles BP, Paris, France, a 1943 graduate of Ecole Polytechnique with a Dr. of Engineering degree.

Charles W. Spalding, Student, Institute of Paper Chemistry, Appleton, Wis., a 1959 graduate of the Institute of Paper Chemistry.

Earl E. Sproul II, Salesman, Riordon Sales Corp., Ltd., New York, N. Y., a 1953 graduate of Trinity College.

Adrianns W. Swets, Director, Swets & Zeittinger, Amsterdam, Holland, a 1936 graduate of Technical University, Delft, with a doctor's degree.

Hayden A. Taylor, Advertising Manager, Black-Clawson Co., Middletown, Ohio. Attended University of Cincinnati.

Augusto G. Terracini, Research, Industrias Argentinas del Papel S. A., Buenos Aires, Argentina.

Pieter H. Teunissen, Director, Straw Pulp Mill, Algemene Kunstzijdo Unie N. V., Arnhem, Holland, a 1936 graduate of Leiden College with a doctor's degree.

Robert Thiollet, Director of Service and Applications, Compagnie Française des Matiéres Colorantes, St. Denis, Seine, France, a 1925 graduate of Ecole Nationale Superieure de Chimie de Paris.

William L. Thomas, Physicist, Mason Firth & McCutcheon Pty., Ltd., Melbourne, Australia, a 1957 graduate of Melbourne University.

Jerome C. Timen, Sales Engineer, Johns-Manville Products Corp., New York, N. Y., a 1956 graduate of Dickinson College.

Carl A. Turk, Sales Manager, Ortman-McCain Co., Chicago, Ill.

Vincent H. Turner, District Manager, Dynamatic Div., Eaton Mfg. Co., Philadelphia, Pa. Attended Pennsylvania State University.

William Van Koevering, Group Leader, St. Regis Paper Co., New York, N. Y., a 1950 graduate of St. Lawrence University.

Todd C. Walker, Manager, Sales Development, Firestone Plastics Div., Firestone Tire & Rubber Co., Pottstown, Pa., a 1956 graduate of Lafayette College.

Robert C. Warren, Sales Engineer, Jesse W. Eakins Co., Detroit, Mich., a 1952 graduate of Albion College.

George H. Webster, Manager, New Products Development, Canadian International Paper Co., Montreal, Que., Canada, a 1953 graduate of University of Toronto.

Hermann G. Weiss, Research Engineer, St. Regis Paper Co., Deferiet, N. Y., a 1954 graduate of Technical University, Darmstadt.

Bjorn E. Werenskiold, Sales Supervisor, Canadian Vickers, Ltd., Montreal, Que., Canada, a 1950 graduate of Linz Engineering College, Austria.

Frederick S. White, Librarian, Texas Engineers Library, College Station, Tex.

Lloyd Wingerd, Chemist, American Bitumuls & Asphalt Co., Emeryville, Calif., a 1948 graduate of Duquesne University.

Howard L. Wolsted, Process Development Superintendent, Film Div., Olin Mathieson Chemical Corp., Covington, Ind., a 1942 graduate of Iowa State College.

C. Nelson Wood, Mechanical Designer, Dorr-Oliver, Inc., Stamford, Conn. Attended Queen's University and University of Cincinnati.

Lowell W. Zabel, Superintendent, Instrumentation Lab., Kimberly-Clark Corp., Neenah, Wis., a 1935 graduate of Lawrence College.

Appointments

Edward J. Albert, Chairman of Thwing-Albert Instrument Co., Philadelphia, Pa., was awarded the SAMA Award of the Scientific Apparatus Makers Association at its meeting at Boca Raton, Fla., on March 30, 1960.

Carl D. Amsden is now Chief Chemist of the Owens-Illinois Glass Co. paper mill at Valdosta, Ga.

William D. Andrew, formerly of Knowlton Bros., is now Night Superintendent of the Merrimac Paper Co., Lawrence, Mass.

Hanns F. Arledter is now Director of Research for the Mead-Hurlbut Research Laboratory of the Mead Corp., Chillicothe, Ohio.

Ernest D. Childers, formerly of Bowaters Southern Paper Corp., is now a Chemical Engineer with Tasman Pulp & Paper Co., Ltd., Kawerau, New Zealand.

Allison C. Clough, formerly of Chase Bag Co., is now a Sales Representative of Longview Fibre Co., Longview, Wash.

Jacques Duret, formerly of CDNPA, is now Engineer for Papeteries de Gascogne, Landes, France.

James H. Dutruc, formerly of Papeteries Chancel, is now Sales Engineer for Ateliers Allibe Cie., Fures, France.

John M. Elder is now Chief Chemist for Weyerhaeuser Timber Co., Everett, Wash.

Howard P. Espenmiller is now Director of Research and Development of the Black-Clawson Co., Middletown, Ohio.

Robert C. Etnire, formerly of River Raisin Paper Co., is now Vice-President of Stuart Hall Co., Kansas City, Mo.

Fabio G. Fonda, formerly of South Africa Ind. Cellulose Corp. is now Pulp Mill Manager of Soc. Agri. Ind. per la Cellulosa, Torviscosa, Italy.

John M. Fulton is now General Manager of the Northwest Lumber and Plywood Division of the Crown Zellerbach Corp., Portland, Ore.

Warren A. Girard, formerly of Valentine Pulp & Paper Co., is now a Design Engineer for Grace Paper Co., New York, N. Y.

Henry S. Godshall, Jr., formerly of Marinette Paper Co., is now Plant Manager of Cia Industrial de San Cristobal S/A, Mexico, D. F.

Norman L. Greenman is now Vice-President of Rogers Corp., Rogers, Conn.

Donald S. Greif is now Supervisor of Coating Applications for the National Starch & Chemicals Co., Plainfield, N. J.

Frank R. Hamilton, formerly of Simpson Paper Co., is now Paper Mill Production Manager for Bergstrom Paper Co., Neenah, Wis.

Walker Hamilton, Jr., formerly of the Orchard Paper Co., is now Manager of Laminating Paper Sales for the Fitchburg Paper Co., Fitchburg, Mass.

John A. Harpham is now Manager of the Virginia Cellulose Research Division of Hercules Powder Co., Wilmington, Del.

Hans Hess is now Technical Manager of Papierfabrik Utzendorf, Utzendorf, Switzerland.

Robert W. Hisey is now Chief Engineer of S. D. Warren Co., Cumberland Mills, Me.

George N. Holme, formerly of Stone Container Corp., is now Senior Research Engineer for R. R. Donnelley & Sons Co., Chicago, Ill.

Alfred T. Hurter is now President of Stadler, Hurter & Co., Montreal, P. Q., Canada.

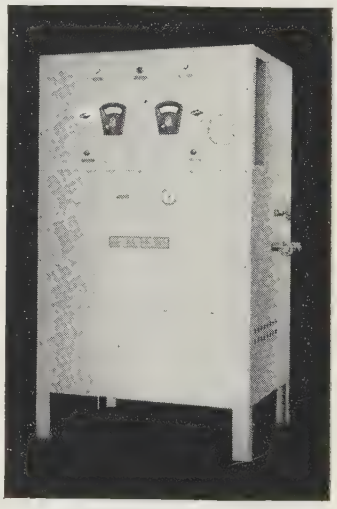
John C. Hyatt, formerly of American Cyanamid Co., is now with Nicolet Paper Corp., West De Pere, Wis.

Milton V. Jones is now Division Engineer of the Mead Corp., Chillicothe, Ohio.

Krishna K. Khandelwal, formerly of Dewey & Almy Co., is now a Development Engineer for the Beloit Iron Works, Beloit, Wis.

YM

Heat Transfer Systems



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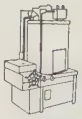

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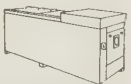

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Robert W. Kitchel of Hercules Powder Co. has been transferred from New York, N. Y., to Detroit, Mich., as a Technical Sales Representative of the Virginia Cellulose Department.

Edward J. Klaczkiewicz, formerly of Pusey & Jones Corp., is now a Staff Engineer for the Beloit Eastern Corp., Downingtown, Pa.

Frank A. Knight is now Division Manager of the Eastern Fine Papers Division of Standard Packaging Corp., Bangor, Me.

Maurice J. Kelly of Hercules Powder Co. has been transferred from New Orleans, La., to Wilmington, Del., as a Technical Sales Engineer.

Charles M. Koon is now Resident Manager of the Eastern Fine Paper and Pulp Division of Standard Packaging Corp., Bangor, Me.

Harry L. Larson, formerly of Witco Chemical Co., is now Senior Development Engineer for the Goodyear Tire & Rubber Co., Chemical Products Division, Akron, Ohio.

Russel J. Le Roux is now Manager of Manufacturing of the Pulp and Paper Division of Weyerhaeuser Timber Co., Everett, Wash.

Orlando J. Losada, formerly of Copaca S/A, is now Technical Director of Papelera Mar Del Plato S/A, Buenos Aires, Argentina.

James E. Luce is now a Chemist for Industrial Cellulose Research Ltd., Hawkesbury, Ont., Canada.

John M. Mallory is now Assistant Superintendent of the paper mill of Union Bag-Camp Paper Corp., Savannah, Ga.

Ernest C. Manders, formerly of Kimberly-Clark Corp., is now Resident Manager of Menasha Wooden Ware Corp., North Bend, Ore.

William W. Marteny of Owens-Illinois Glass Co. has been transferred from Jacksonville, Fla., to Toledo, Ohio, as Chief of Pulping Research and Development.

John E. Maxson is now Executive Vice-President of Stebbins Engineering & Mfg. Co., Watertown, N. Y.

John M. McEwen is now Manager of the Everett, Wash., mill of the Weyerhaeuser Timber Co.

Karl R. Meyer, formerly of E. B. Eddy Co., is now a Project Manager for Stadler-Hurter Co., Montreal, Canada.

George Morley, formerly of the Black-Clawson Co., is now a Senior Draftsman for the Champion Paper & Fibre Co., Hamilton, Ohio.

Jarrell B. Mugg, formerly of the U. S. Army, is now a Research Engineer for the Crown Zellerbach Corp., Camas, Wash.

William P. Nesbitt is now General Manager of the Pulp and Paper Division of Howard Smith Paper Mills, Ltd., Cornwall, Ont.

Edward Novick, formerly a Student at the University of Pennsylvania, is now in the Engineering Chemical Sales Department of the Dow Chemical Co., Midland, Mich.

Earl S. Packard is now Technical Director of the Chemical Fine Paper & Board Division of Standard Packaging Corp., Holyoke, Mass.

John H. Payne, formerly of Hudson Pulp & Paper Co., is now Production Engineer for Riegel Paper Corp., New York, N. Y.

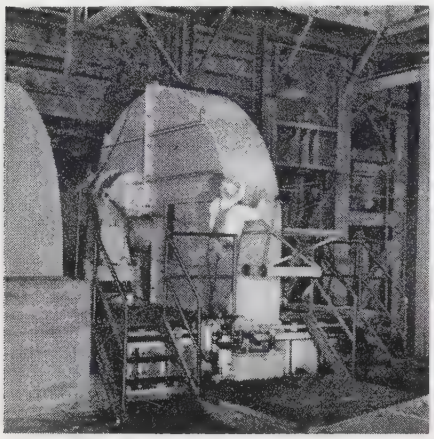
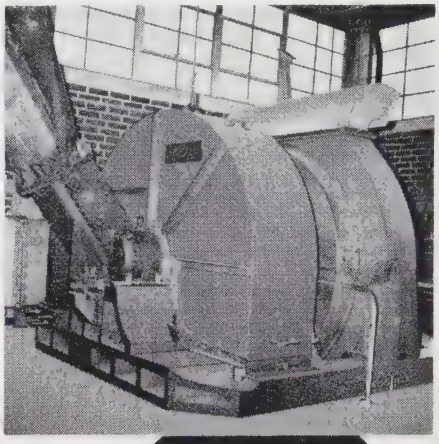
Joseph C. Pullman is now Technical Manager for General Chemicals, Cyanamid International Division, American Cyanamid Co., New York, N. Y.

Kenneth L. Rawlinson is now Manager of the Mittag Division of the Burroughs Corp., Park Ridge, N. J.

Charles W. Richards of the International Paper Co. has been transferred from Palmer, N. Y., to New York City as a Technical Representative.

Karl L. Rohde, formerly of Dewey & Almy Chemical Co., is now Vice-President in Charge of Sales for Mayelle Enterprises, Winter Park, Fla.

Ernest E. St. Louis, formerly of the Southern Textile Chemical Corp., is now

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Technical Coordinator of Metro-Atlantic Corp., Centredale, R. I.

Herbert E. Schmidt, formerly of Abitibi Power & Paper Co., is now a Project Engineer for Fried. Krupp Industrieban "F," Essen, Germany.

Fred C. Shanaman has retired as President of Pennsalt Chemical Corp. of Washington, Tacoma, Wash., and will continue as a Consultant to the company.

Harry S. Spencer is now Vice-President of the Alliance Paper Mills, Merritton, Ont., Canada.

Nathan Sugarman, formerly of North American Rayon Corp., is now a Research Chemist for the Chicopee Mfg. Corp., Milltown, N. J.

Otto C. Sylwan, formerly of Canada Paper Co., is now with the UN Technical Assistance Board, Department of Economic Affairs, New Delhi, India.

Jacob J. Thigpen, Jr., formerly Student at North Carolina State College, is now a Chemist for P. H. Glatfelter Co., Spring Grove, Pa.

Peter S. Thomas, formerly of the Brown Co., is now a Product Development Chemist in the Silicone Products Department of General Electric Co., Waterford, N. Y.

Paul E. Truttschel is now Vice-President and Sales Manager of the Appleton Coated Paper Co., Appleton, Wis.

Edward H. Tutun, formerly of Dewey & Almy Chemical Division of W. R. Grace Co., is now with the Vellumold Co., Worcester, Mass.

Edward Vanzo, formerly of the Dixie Cup Co., is now a Graduate Student at the College of Forestry, State University of New York, Syracuse, N. Y.

William J. Verross of the West Virginia Pulp & Paper Co. has been transferred from Covington, Va., to Charleston, S. C., as General Superintendent.

John Verwayen is now Division Manager of the Mead Corp., North Bergen, N. J.

Henry Wallgren, formerly of Sandvik Canadian, Ltd., is now a Chemical Engineer for Vulcan-Cincinnati, Inc., Cincinnati, Ohio.

Donald J. Wehrenberg, formerly of Union Bag-Camp Paper Corp., is now a Chemical Engineer in the Pulp and Paper Section, Inorganic Research & Development Department, Food Machinery & Chemical Corp., Princeton, N. J.

Otha Winningham, formerly of Bowaters Southern Paper Corp., is now Manager of Pulp and Paper Manufacture for the Hudson Pulp & Paper Co., Palatka, Fla.

* * *

G. Derangere has succeeded *Lovell M. Cushing* as the official representative of La Cellulose d'Aquitaine, St. Gaudens, France, in the Technical Association.

L. A. Paterson has succeeded *D. Neubauer* as the official corporate representative in TAPPI of Tasman Pulp & Paper Co., Ltd., Kawerau, Bay of Plenty, New Zealand.

* * *

Thomas S. Morse, Manager of Sales Service, has succeeded *P. F. Neumann* as the official representative of the Hercules Powder Co. in TAPPI.

G. W. Kalotschke, Techincal Consultant, has succeeded *Rex Vincent* as the official representative in TAPPI of Bulkley, Dunton Pulp Co., Inc., New York, N. Y.

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This control, the V-notch, does the job completely.
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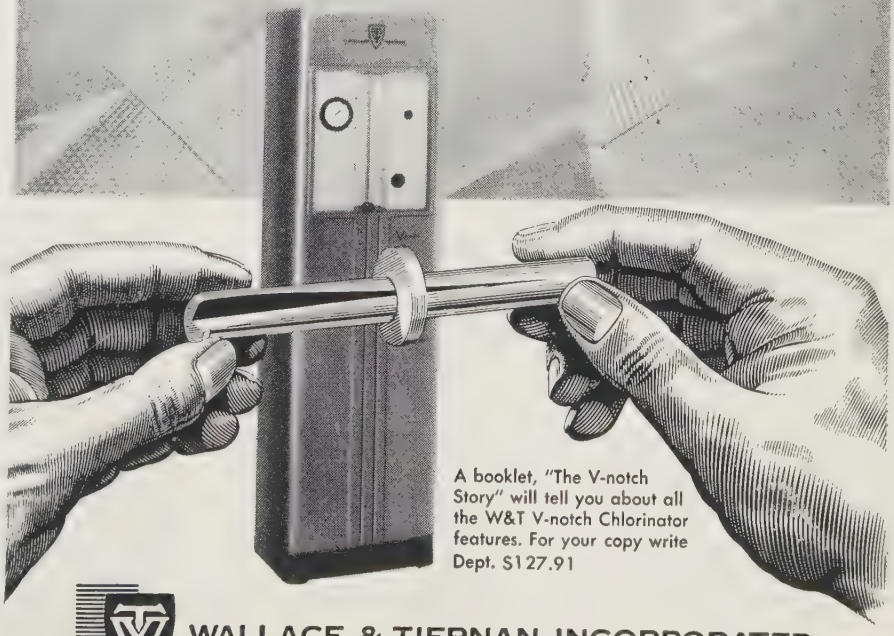

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INDUSTRY NOTES

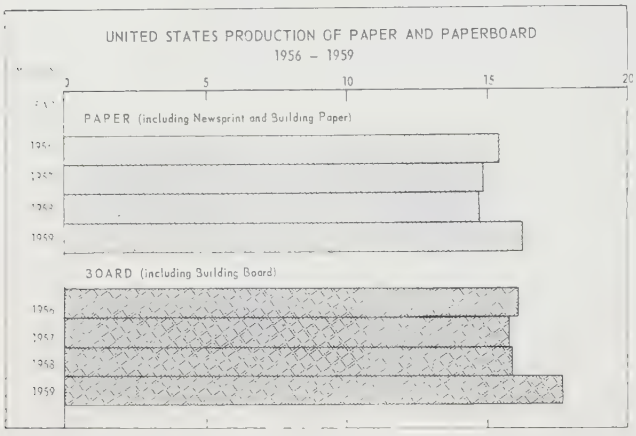
North American

Statistics

*Paper and Paperboard in 1959**

Production of paper and paperboard in January, 1960 totaled approximately 2.8 million tons, 2% higher than production in January, 1959. Paper production in January, 1960, was approximately 1.3 million tons, a 4% increase over January, 1959; paperboard production was also about 1.3 million tons, up 1%; production of building paper and board in January, 1960, was slightly lower than in January, 1959.

The chart below indicates the magnitude of the 1959 production increase over the three previous years.



Pulpwood

Total receipts of pulpwood for the year of 1959 were 38,186,000 cords, an increase of 3,890,000 cords over receipts for the comparable period of 1958. Domestic receipts were 3,976,000 cords above the year earlier total, while imports declined 86,000 cords. All of the regions showed increases ranging from 4% in the Northeast, to 17% in South Atlantic.

Pulpwood consumption for the year 1959 was 38,797,000 cords, an increase of 3,771,000 cords over the same period of 1958. All of the regions showed increases ranging from 4% Northeast to 15% South Atlantic.

Inventories of pulpwood at the end of December were 5,203,000 cords, an increase of 298,000 cords above November, 1959, and a 734,000 cords decline from December last year. All of the regions showed decreases ranging from 6% South Atlantic to 17% North East.

Wastepaper and Other Fibrous Materials

December wastepaper receipts were 747,000 tons; for the year they totaled 9,333,000 tons, an increase of 709,000 tons above receipts for last year.

Waste paper consumption for December was 721,000 tons; the January–December total was 9,176,000 tons, an increase of 470,000 tons above consumption for 1958.

Inventories at the end of December were 578,000 tons, an increase of 26,000 tons above November, and 112,000 tons above inventories at the end of December 1958.

Consumption of total fibrous materials for December was 794,000 tons; the January-December total was 10,201,000 tons, an increase of 1,165,000 tons above consumption for 1958.

Inventories of total fibrous materials at the end of December were 1,057,000 tons, 54,000 tons above November and 84,000 tons above inventories at the end of December, 1958.

Wood Pulp

Production of wood pulp for the year 1959 was 24,161,000 tons, an increase of 2,644,000 tons above the comparable 1958 total.

Wood pulp consumption in the manufacture of paper and board for the year 1959 was 25,058,000 tons, an increase of 2,740,000 tons above consumption for the year 1958.

Imports of wood pulp for January-December 1959 were 2,443,682 tons, an increase of 20% above imports for last year. Imports from Canada for the year 1959 were 1,983,267 tons, an increase of 9% over the comparable period of 1958. Overseas imports for the year 1959 were 453,625 tons as compared to 282,486 tons in the year 1958.

Exports of wood pulp for the year were 652,526 tons, as against 505,214 tons exported during the same period last year.

Inventories of wood pulp at paper and board mills at the end of December were 533,000 tons, an increase of 7000 tons above inventories at the end of November and 12,000 tons below inventories at the end of December, 1958.

* APPA, *Monthly Statistical Summary* 38, No. 3 (March, 1960).

Mexican

Mexico

Startup of Continuous Straw Pulp Mill

Empaques de Carton Titan, S.A., in Monterrey, Mexico, reports the successful startup of its new 60-ton (metric)per day Pandia continuous pulp mill, producing unbleached pulp from wheat straw for corrugating medium. News of the startup came to Parsons & Whittemore, Inc., supplier of the principal equipment.

The Pandia continuous digester, built by The Black-Clawson Co., consists of two 42-in. digester tubes complete with Pandia discharger, chemical supply pump, drives and live bottom blow tank.

Parsons & Whittemore also furnished for this project principal items of stock preparation equipment including a Black-Clawson Hydrapulper, pumps and stock agitators.

Overseas

Great Britain

National Paper Museum

The appeal to British industry for funds to set up a national paper museum has met with a very ready response and the trust fund for the establishment of the museum has reached the sum of £725 ($2030). Money is still being received and this now makes it possible to prepare the premises that have been leased for the museum at St. Mary Cray. Donations from interested companies and persons overseas will, of course, be equally welcomed by the Museum Committee, J. Barcham Green, Sr., Chairman.

This is a project that has been sponsored by the Technical Section of the British Paper and Board Makers' Association, St. Winifred's, Welcomes Road, Kenley, Surrey.

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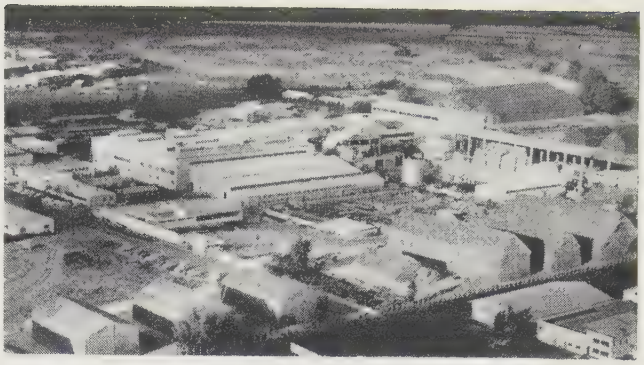
For more information on DeZurik Control Valves write for Bulletin 300.

DeZURIK CORPORATION
SARTELL, MINNESOTA



Aerial view of the American Israeli Paper Mills at Hadera, Israel

tific institutions, has provided Israel with a successful new pulp mill and another basic industry.

When the American Israeli Paper Mills, founded in 1951 and located in Hadera, decided that the only method of ensuring a plentiful and continuous supply of paper was to reduce the plant's dependence on imported raw materials, steps were taken to develop local materials that could be used by a projected pulp mill. Parsons and Whittemore (Inc.,) was hired to make a survey of the raw materials available in Israel. This group was headed by W. Chidester, who was on leave as Chief of the U. S. Forest Products Laboratory at Madison, Wis. Dr. Lionel Alfassa, Chief Chemist of AIPM, represented the company on the project. On the basis of their report a $60,000 research program was undertaken by the company to determine the feasibility of using local raw materials. The problem was to find materials with a high pulp yield, readily available and which coud be collected economically. Extensive laboratory tests and pilot projects carried out by the Forest Products Laboratory showed straw and cornstalks to have a 40 to 45% pulp yield, which compares favorably with pulp yields from wood. Since corn is primarily grown with irrigation and is not dependent on erratic winter rainfall, a reasonable stable supply makes it readily available.

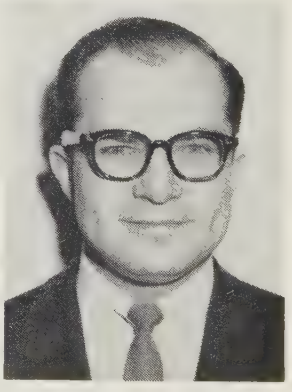
The successful establishment of a going paper industry and the manufacture of pulp from straw and cornstalks can be classed as one of the major industrial achievements of the young State of Israel. By supplying the paper mill with 50% of its raw material requirements the pulp mill will decrease the country's dependence on imports and increase its economic independence.

Pulp and Paper Manufacturers and Converters

John W. Bolton & Sons, Inc.

Appointment

Paul A. Halas, of Chicago, has joined the sales staff of the Machine Knife Division, John W. Bolton & Sons, Inc., Lawrence, Mass. Mr. Halas will cover the territory including Chicago and most of Illinois, Wisconsin, and sections of Indiana, Minnesota and Iowa.



Paul A. Halas

Calcasieu Paper Co.

Clupak Production

Calcasieu Paper Co., of Jacksonville, Fla., one of the 12 paper companies having license agreements with Clupak, Inc., to make Clupak extensible paper, has just begun production of the new paper.

Installed on its no. 3, 162-in. wide machine, at its Elizabeth, La., plant, Calcasieu's new extensible unit has the capacity to produce a wide variety of kraft papers at the rate of approximately 150 tons a day.

Clupak, Inc.

Bag Strengths Tested for Cement Industry

A year-long series of rigidly-controlled breakage tests on commercial-run multiwall cement bags has shown that bags made of Clupak "stretchable" paper withstand up to six times the punishment of regular kraft multiwalls of considerably heavier basis weight.

The tests were conducted with bags made out of standard commercial runs of paper. Both the Clupak paper (first introduced in 1958, and now widely used in all forms of multiwalls) and the regular kraft were manufactured on the identical paper machine, using pulp produced in the Southern United States.

The tests—repeated flat drops from a 4-ft. height until the bags broke—were under standard laboratory conditions of 73°F. and 50% R.H. Best performance was that of three-ply Clupak bags with total paper basis weight of 150 lb. (each containing 94 lb. of cement) which averaged 18.2 drops to failure. Against this, four-ply regular kraft bags with higher basis weights of 170 and 180 averaged 3 and 3.8 drops to failure, respectively.

Fibreboard Paper Products Corp.

Tube and Can Division

Formation of a completely new manufacturing and merchandising unit, the Tube and Can Division, was announced by Fibreboard Paper Products Corp. William H. Ecker was named as general manager of the unit by Jack H. Grady, vice-president and general manager, packaging group.

Koppers

Super "Dust Catcher" Being Installed

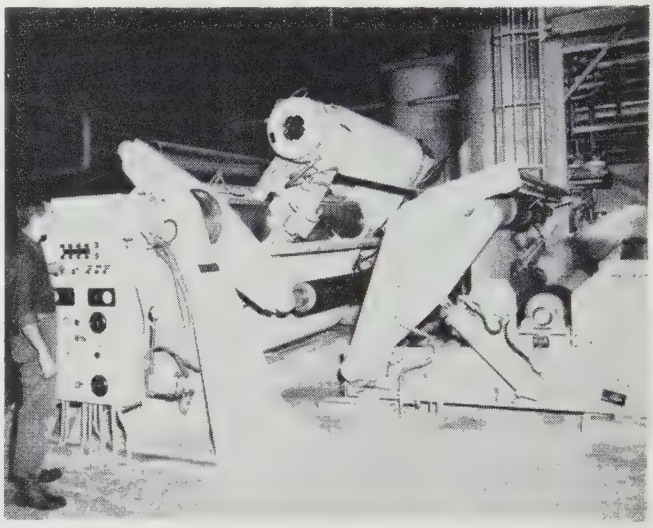
Fibreboard Paper is installing a new electrostatic "dust catcher" as part of its big expansion at the San Joaquin Pulp and Paperboard mill, Antioch, Calif. The new dust catcher is designed to give greater efficiency than ever before attained in this type of operation.

The dust catcher is an electrostatic precipitator, designed and built by the Metal Products Division of Koppers Co., Inc.

International Paper Co.

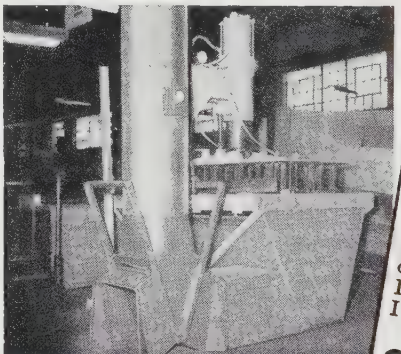
World's Largest Unwind-Splicer Installed

IPC has installed what is believed to be the world's largest



The unwind-splicer at Moss Point, Miss.

Automatic disposal of large broke sheets accomplished with use of crusher-shredder. Shredded pieces flow easily thru system, and are ready for proper baling or reprocessing.



Automatic trim removal from box stripper also provides a floor level pick up to keep the entire area clear.

5 IDEAS FOR INCREASING PRODUCTION with OBP PNEUMATIC PAPER TRIM REMOVAL SYSTEMS

Let us show you how our experience can help you. Call today. We do the entire job — ENGINEERING — MANUFACTURING — INSTALLING.

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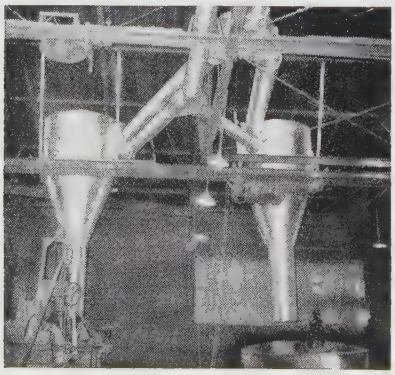
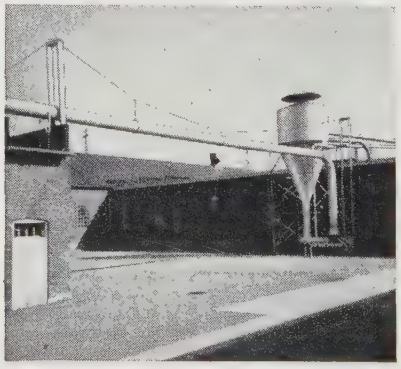
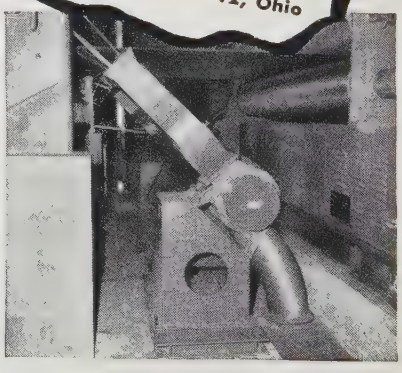


Reprocessing of boxboard trim. Two collectors, and special switching valves permit discharge of trim into *either* of two beaters.



Catenary suspension used to keep yard clear. Pipe runs from transfer collector to separate reprocessing location. Twenty feet of head room allowed for trucks and equipment.



Continuous trim made ready for reprocessing or baling with automatic cutter which is designed as an integral part of the pneumatic system. Cutter accepts continuous lengths of solid fibre to 3/16" thickness, chipboard to 1/4" thickness, widths to 7".

unwind and automatic splicer at its mill in Moss Point, Miss.

The unwind-splicer, supplied by the Waldron-Hartig Division of the Midland-Ross Corp., New Brunswick, N. J., feeds paper up to 152 in. wide to off-machine coating equipment. It is built to handle rolls measuring up to 5 ft. in diam. and weighing up to 7 tons. It is designed for future operation at 2000 f.p.m. and is presently run at speeds up to 1000 f.p.m. The unit is operated by one man who controls unwinder and splicer operations from a push-button control panel.

Paper-Plastics Sales Div.

A new division, the Paper-Plastics Sales Div., has been formed by IPC.

The new division will be headed by J. L. DeRose, division sales manager, who will make his headquarters in the company's executive offices in New York, N. Y.

John A. Manning Paper Co., Inc.

Okra Gum As Wet-End Additive

The development of a highly effective, water-soluble vegetable gum has been announced by the John A. Manning Paper Co., Inc., Troy, N. Y. Derived from okra, the gum was developed to provide a domestic deflocculating agent for long fibers in specialty paper manufacturing.

In the mill, okra is prepared directly in a dilute water dispersion which is added to the paper process anywhere from the beater to the head box. The gum greatly enhances sheet formation and increases tensile strength by uniform fiber distribution. For highest efficiency and the elimination of residue, 200-mesh gum is recommended.

More information about okra gum in paper manufacturing from the distributor, Morningstar-Paisley, Inc., 630 W. 51st St., New York, N. Y.

The Mead Corp.

Appointment

J. John Verwayen has been named division manager of the Mead's paperboard mill at North Bergen, N. J. Prior to this promotion, Mr. Verwayen had been chief engineer for the mill and the adjacent Mead Containers plant for 13 years.

Nekoosa-Edwards Paper Co.

Nekoosa-Edwards Foundation Scholarships

Four Central Wisconsin high school seniors have been named recipients of $500 scholarship awards presented by Nekoosa-Edwards Foundation. The winners are Debby Copeland, Pittsville High School; Joanne Painter, Alexander High School; Sandra Lee Long, Alexander High School; and Douglas Berryman, John Edwards High School.

The 1960 winners make a total of 32 students who have received awards since the scholarship program was introduced in 1953. The foundation was established in 1947 by Nekoosa-Edwards Paper Co., a leading producer of business papers.

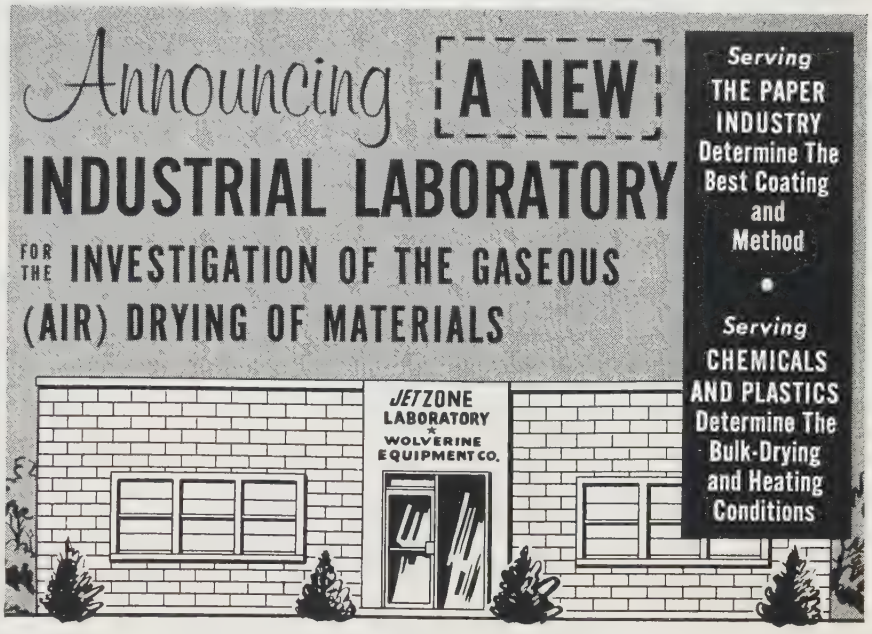
Paterson Pacific Parchment Co.

High-Capacity, High-Speed Flexographic Printing Press

Paterson Pacific, a subsidiary of the Paterson Parchment Paper Co., Bristol, Pa., has announced installation of a new four-color, Flexographic printing press.

Purchased and installed at a cost of $75,000, the high-capacity, high-speed unit was manufactured by Windmoller and Holscher, Westfalen, Germany.

Built on a six-color frame, so that two additional colors can be added when desired, the new machine can handle a web of paper up to 42 1/2 in. wide. Its maximum printing repeat range is 36 in. Minimum range is 9 in., with 1/4 in. circular pitch gears. The press is built to operate at a speed of 750 f.p.m.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WOLVERINE EQUIPMENT CO.
Serving THE PAPER INDUSTRY Determine The Best Coating and Method
Serving CHEMICALS AND PLASTICS Determine The Bulk-Drying and Heating Conditions

Three Pilot Lines

LINE 1 A Universal 3-Zone Conveyerized Oven — Interchangeable air projection plates above and below — Temperature 70-600° — Low and high velocity 400-10,000 ft. per min. — 24" wide conveyor with wide range drive — All zones individually retractable from conveyor line — Steam injection for humidity control all zones — Zoned horizontally as well as vertically.

Purpose: Drying and curing of wet material — Coated webs, coated objects, plastics, impregnated webs, etc. — Arranged for quick determinations on all products by the "Miniaturized" sample car method.

Preceded by: Coater, impregnating tanks and squeeze rolls.

LINE 2 Two Zone Dryer, Heater or Cooler for Particulate Matter (pelletized material — chopped material — crystals). Works by aerating a bed of material on belt conveyor — Velocity range 1000-10,000 ft. per min. — Temperature 45°-600° — Arranged for separation of fines — 12" wide belt conveyor.

Purpose: Drying, heating, cooling of particles of material.

Preceded by: Feeder or pelletizer.

LINE 3 Super Speed High Velocity 4-Zone Arch Dryer for Coated Web Material — Carries 24" web on rolls or belt — Velocity 400-12,000 ft. per min. — Temperature 70-600°F — Proved drying capacity (clay latex) 2800 ft. per min.

Purpose: Proving coatings and coating methods.

Preceded by: Coaters by different manufacturers.

Plus — Precision Batch Dryer — Basis Weight Scales, Thermocouples, Thermometer, Mixing Equipment, Etc.

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JETZONE LABORATORY DIV.

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Increase Your Output of QUALITY ROLLS with LOW COST Tidland PNEUMATIC CHUCKS

FOR ALL OVERSIZED CORES 6″ IN DIAMETER AND UP

Picture shows chuck being inserted in core; outside face of chuck and outer edge of core flush when in operation.

EASILY ADAPTABLE TO SHAFTLESS UNWIND | ELIMINATES CORE DAMAGE | FAST, EASY TO USE

Here is a chuck that was developed "in the plant, on the job" to meet the demand of the paper industry for a chuck for use with large diameter cores in the high-speed production of quality rolls with NO CORE DAMAGE.

Tidland pneumatic chucks are designed to hold the core in an accurately centered position without slippage to obtain true winding and unwinding of paper. In addition the chuck gives these advantages:

1. SPEEDS ROLL CHANGING . . . chuck is quickly and easily removed. Chuck deflates in seconds.

2. NO DAMAGE TO CORES . . . pneumatic chuck grips the core with an even firm pressure that prevents slipping. The rubber tire will not wear, gouge, bend, dent, or in any way damage the core.

3. MINIMUM MAINTENANCE AND REPLACEMENT COSTS . . . the pneumatic chuck is made of a few simple parts, requiring little or no service.

The Tidland Pneumatic Chuck is manufactured of tenzaloy cast aluminum, with a rubber tire for a no-slip grip on the core. Available in various sizes to fit cores from 6″ to 14″ (inside diameter) and for either square or round shafts.

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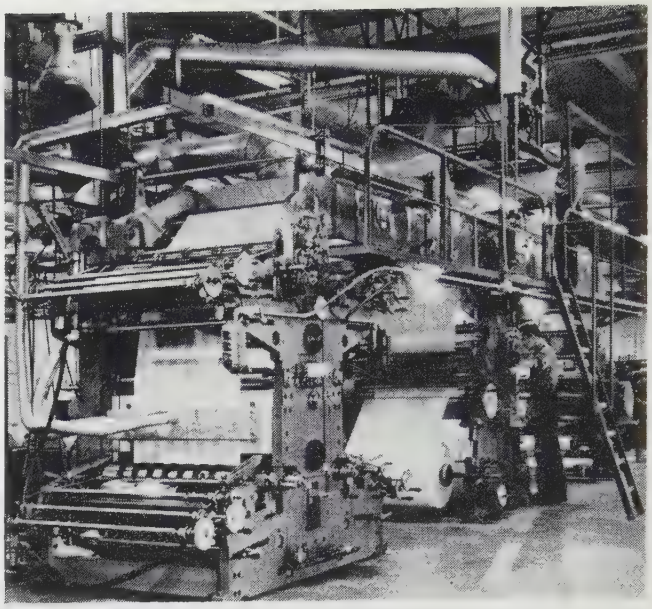


Patterson Pacific's new Flexographic press

St. Regis Paper Co.

Southland to Manufacture Kraft Paper

St. Regis Paper Co. announces that it has made an agreement with Southland Paper Mills of Lufkin, Tex., for the manufacture of kraft paper on one of Southland's four paper machines. The output of kraft paper will be available to St. Regis and Perkins-Goodwin Co.

Southland is now in the process of installing the necessary equipment for converting the paper machine to the manufacture of kraft paper.

Fellowships and Scholarships

St. Regis is again offering two fellowships in forestry in addition to five undergraduate scholarships in also forestry. The fellowships are valued at $1000 each, and are given for one year.

Winners of the two St. Regis Fellowships in forestry this year are John P. Butt of the New York State College of Forestry and Gerald R. Stairs of the Talc University School of Forestry.

Scott Paper Co.

Delaware County Research Center

Scott Paper has awarded a general contract to Wigton-Abbott Corp. of Plainfield, N. J., for the construction of its new Research Center in Delaware County, adjacent to the Philadelphia International Airport.

The foundation of the Research Center, under a separate contract with Wigton-Abbott, had already been under construction.

It is estimated that the Research Center, which will provide 152,000 sq. ft. of space for the company's research and engineering personnel, will be ready for occupancy in May ,1961.

West Virginia Pulp and Paper Co.

HiYield Printkote

A high yield bleached board with a coated surface recommended for printing has been developed for the first time by the Bleached Board Division of West Virginia Pulp and Paper.

The new board, called HiYield Printkote, will enable firms in the packaging field, now using nonvirgin fiber printing boards including some of the lowest grades, to upgrade cartons which are all white inside and out, made of 100% virgin bleached fiber.

More information from Bleached Board Division, West Virginia Pulp and Paper Co., 230 Park Ave., New York 17, N. Y.

Weyerhaeuser Co.

Appointment

Russell J. LeRoux, of Everett, Wash., has been named manager of manufacturing, pulp and paperboard division of Weyerhaeuser.

Mr. LeRoux's appointment will be effective April 1. He succeeds R. E. Baker, who leaves the company to join Southwest Forest Industries of Phoenix, Ariz.

Recent changes in management personnel of the shipping container and milk carton divisions have also been announced.

Kenneth Cook replaces John A. Conboy as plant manager of the company's milk carton branch at Harmony, Penn. Conboy moves to the Camden, N. J. branch.

Walter B. Duggan was named resident manager of the Baltimore, Md. shipping container branch. He has been sales manager at this branch since 1952.

John C. O'Brien becomes manager of Weyerhaeuser's milk carton branch in Whittier, Calif. O'Brien was formerly office manager of the Carpentersville, Ill., branch.

Educational Institution

U. of Maine

U. of M. Pulp and Paper Alumni Luncheon. About 150 graduates and friends of the University of Maine connected with the pulp and paper and allied industries attended an alumni luncheon at the Biltmore Hotel in New York City on Wednesday, February 24, during Paper Week. James A. Gannett, resident secretary of the U. of Maine Pulp and Paper Foundation and retired registrar of the University, was presented with the Foundation's 1960 Honor Award. J. L. Ober, Beverly, Mass., retired vice-president of the Scott Paper Co., who is president of the Foundation, made the presentation. Robert N. Zabe, an engineer with Charles T. Main, Inc., Boston, Mass., was chairman for the meeting. The speaker was William M. Hall, president of Charles T. Main, Inc.

Previous Honor Award winners who were invited as guests at the luncheon were as follows: Dr. Ralph H. McKee, New York, who aided in establishing the first course in pulp and paper technology in the country at the University of Maine in 1913; George D. Bearce, Bucksport, Me., former general manager of St. Regis Paper Co.'s operation in Maine; C. E. Libby, professor of pulp and paper technology in the School of Forestry at North Carolina State College of Agriculture and Engineering; Professor Lyle C. Jenness, head of the department of chemical engineering at Maine; Clifford Patch, retired technical director of the Eastern Corp., Bangor, Me.; George E. Dyke, New York, president and chairman of the board of Robert Gair Co., Inc.; George Olmsted, Jr., Boston, president of the S. D. Warren Co.; Dr. Ashley S. Campbell, Tufts University, former dean of the U. of M. College of Technology; and William Chisholm representing his father, the late Hugh J. Chisholm, who was president of the board of the Oxford Paper Co.

Pulp & Paper Research Institute of Canada

Effective Jan. 1, 1960, the titles "Principal Scientist," "Principal Engineer," or "Principal Technical Specialist," as appropriate, will be conferred on a few of the senior staff of the Pulp and Paper Research Institute of Canada who have achieved world-wide distinction and who have made outstanding contributions over a period of many years. This is a generic term, and the holder of the title could sign himself as "Principal Physicist" or "Principal Physical Chemist," or "Principal Microscopist," etc., as appropriate.

The use of the word "Principal" in professional titles has come into rather general use in Canada and in the United States. In Canada it is used by the National Research Council and the Defence Research Board and by corresponding organizations south of the Border. It denotes an individual of high academic and research achievement and senior stature. He may or may not hold concurrently a position which places upon him responsibility for administration.

Although chronological age is not a primary consideration in the Institute's use of this new title, it is not expected that a person would have made a very large number of significant contributions to his field until he is well above 50 years of age.

The first two members of the staff who will be entitled to use this title in their correspondence are Dr. C. B. Purves and Dr. T. N. Kleinert.

University of Maine pulp & paper alumni luncheon, Hotel Biltmore, Feb. 29, 1960

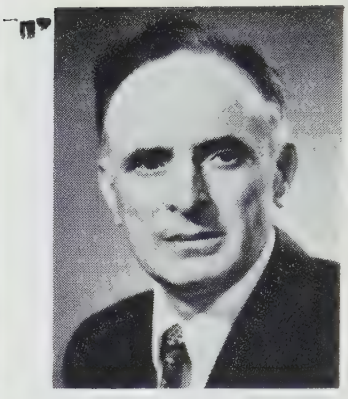
Clifford B. Purves

Clifford Burrough Purves was born at Cupar-Fife, Scotland, and was educated at Bell-Baxter School in the same town. He graduated B.Sc. in Chemistry at the University of St. Andrews, Scotland, in 1923, and then carried out Ph.D. thesis research in the methylated sugar field, graduating Ph.D. in 1929. The years 1926 to 1929 were spent as a Commonwealth Fund Fellow attached to the Polarimetric Division of the U. S. Bureau of Standards, Washington, D. C., where he had the opportunity of studying sugar glucosides.

During 1929–1931, Dr. Purves was a research assistant in the Department of Physiology, Marischal College, Aberdeen, Scotland, and was associated with researches on the metabolism of carbohydrates. In 1931 he was Chemical Foundation of New York Research Associate, at what is now the U. S. National Institute of Health, and gained further experience in the sugar field, particularly with the action of invertase on various methyl fructosides.

During the period 1936 to 1943, he was an Associate Professor of Organic Chemistry at the Massachusetts Institute of Technology, Cambridge, Mass., his special interest being the supervision of Ph.D. thesis research in the cellulose and wood chemistry fields. His present duties as E. B. Eddy Professor of Industrial and Cellulose Chemistry at McGill University, and Head of Wood Chemistry at the Pulp and Paper Research Institute of Canada center about the same interests.

Theodor N. Kleinert



Clifford B. Purves

Together with his graduate students and associates Dr. Purves has published over a hundred papers in the fields of carbohydrates, cellulose and lignin chemistry.

Dr. Purves received the honorary degree of Doctor of Science from Lawrence College, Appleton, Wis., in 1944. During 1956–1957, he was President of the Chemical Institute of Canada.

Theodor N. Kleinert

Born in Vienna, Austria, Dr. Kleinert attended the Technical University there which conferred on him in 1921 the Diploma (M.Sc.) in chemical engineering and in 1924 the degree of D.Sc. From 1921 to 1922 he was a mill chemist at the Salpetre Plant Erwa (near Vienna) in charge of production. In 1924 he became an Assistant Professor at the Technical University of Vienna, and from 1930 to 1939 he was an independent consultant in the fields of cellulose chemistry and chemical pulping in Austria and other European countries.

From 1941 to 1942, Dr. Kleinert was in charge of industrial research in Schlesische Zellulose-und Papierfabriken Ewald Schoeller und Co., and from 1943 to 1953 he was Director of Research of Zellwolle Lenzing Akt. Ges., Lenzing, Austria, a major staple rayon mill. In addition, he lectured on wood and cellulose chemistry at the Technical University of Vienna.

In 1954 Dr. Kleinert was appointed to the staff of the Pulp and Paper Research Institute of Canada as a Senior Scientist.

Although most of his research has been concerned with problems in industrial development, he has also contributed a substantial number of publications dealing with basic and fundamental research in cellulose and lignin chemistry, as well as in the chemistry of viscose fibers. His professional pub-

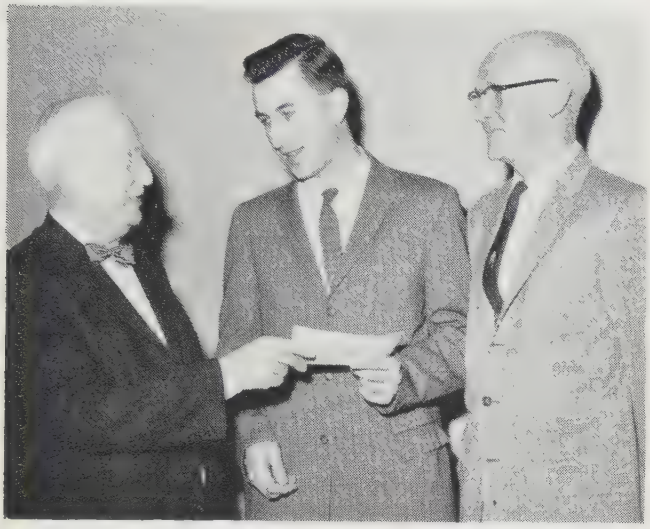
lications number more than a hundred, and he is named as the inventor in some fifty patents.

For his outstanding contributions in scientific and industrial development of the pulp and paper industry of his native country, the Austrian Association of Pulp and Paper Chemists made him, in 1955, the first recipient of its Karl Kellner award, even though he had already emigrated to Canada.

Syracuse College of Forestry

F. C. Boyce Student Award

The Paper Industry Management Association has presented the 9th Annual Fred C. Boyce Student Award to a student at the State University College of Forestry at Syracuse University.



Harry E. Weston, left, secretary-treasurer, PIMA, Chicago, Ill., presents 9th Annual Fred C. Boyce Student Award to Robert C. Peterson of West Nyack, N. Y.

The $200 annual scholarship was awarded to Robert C. Peterson of West Nyack, N. Y., by Harry E. Weston, secretary-treasurer of PIMA. Mr. Peterson is a senior specializing in pulp and paper technology.

Industry Suppliers

Albi Mfg. Co.

Fire-Retardant Paints Explained

A new 12-page illustrated bulletin, "Paint Your Way to Fire Safety," published by the Albi Manufacturing Co., Inc., explains briefly how fire-retardant paint works and how it is applied in all types of industrial, commercial, and institutional buildings to improve personal safety and reduce potential fire damage.

Copies of Bulletin No. 100 may be obtained by writing the Albi Manufacturing Co., Inc., Rockville, Conn.

Allis-Chalmers Manufacturing Co.

Appointments

Robert E. Morris has been appointed manager of the Industries Group's Midwest region. Regional headquarters is located at 1205 Olive St., St. Louis. Mo.

Mr. Morris succeeds C. F. O'Riordan, who has been named manager of the company's North Central region in Chicago.

J. A. Sudduth has been appointed manager of the St. Louis district, and William S. Wright has been appointed manager of the Grand Rapids (Mich.) district.

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For TOP and BOTTOM SLITTER KNIVES
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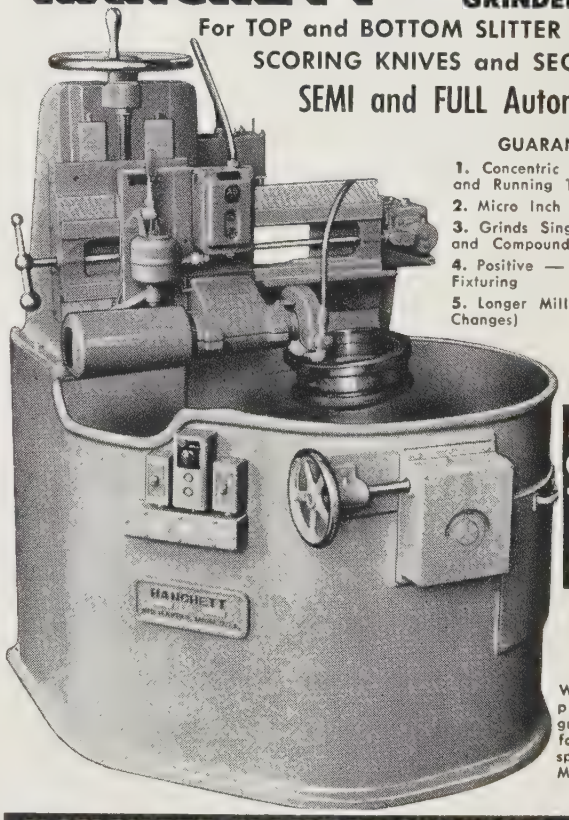

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We are prepared to grind knives for your inspection and Mill Test.

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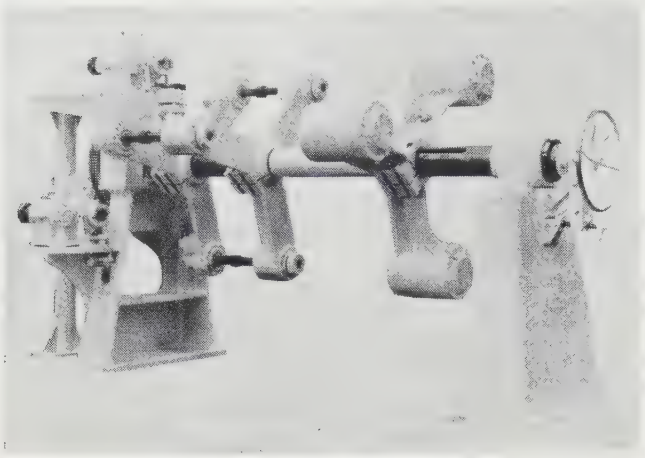
Main Office BIG RAPIDS, MICHIGAN
West Coast PORTLAND 1, OREGON

Appleton Machine Co

3-Arm Reel

The most recent design in 3-arm reels by Appleton Machine Co. points up many improvements in the important area of lessening downtime on windup and unwind operations.

The Appleton 3-arm reel is available for both shaft and shaftless applications. It features three pairs of radial arms



Appleton 3-ram reel

set 120° apart circumferentially. The unwind pair being positioned 60° above the horizontal. The windup pair being located 60° below the horizontal and directly below the unwind. The third pair of arms for unloading finished rolls and loading new rolls is located on the horizontal.

Bailey Meter Co.

Kraft Digester Control

Complete control systems, based on temperature-difference measurement, for direct and indirect heated kraft digesters are shown in new 4-page Bulletin 411. Literature available on request from Bailey Meter Co., 1050 Ivanhoe Road, Cleveland 10, Ohio.

Linear Flow Transmitters

Force balance pneumatic transmitters which extract the square root function, producing a signal varying linearly with rate of flow are described in 4-page Product Specification P22-1. Selection table lists ranges from 0 to 1 in. to 0 to 2000 in. water, service pressures and weights. Literature available on request from manufacturer, Bailey Meter Co.

Baldwin-Ehret-Hill, Inc.

Industrial Insulating Materials

The first catalog published by Baldwin-Ehret-Hill, Inc., contains the full line of over 30 industrial insulations manufactured by this new corporation. Properties and specifications of the complete line of heat and cold insulations for service from subzero up to 1900°F. are presented.

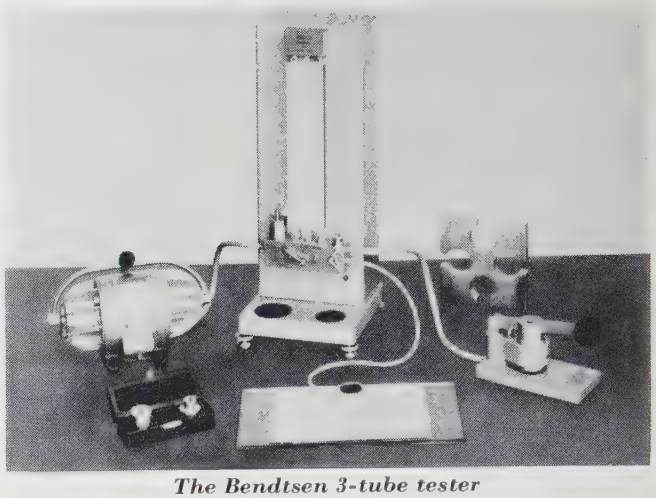
Bauer Bros. Co.

Appointments

The Bauer Bros. Co.; Springfield, Ohio, announces the appointment of E. L. Rastatter as general sales manager.

In this newly created position, Mr. Rastatter will be responsible for all machinery sales in the pulp and paper, food, oil seed, asbestors, and chemical industries.

At the same time M. D. Woodruff was appointed as manager, Cleaner Division. Mr. Woodruff has been associated with The Bauer Bros. Co. since 1928.



The Bendtsen 3-tube tester

Bergstrom Paper Co.

Appointments

Richard C. Peterson, Safety Paper division manager, has been named to head the newly-formed Research and Development department of Bergstrom Paper Co.

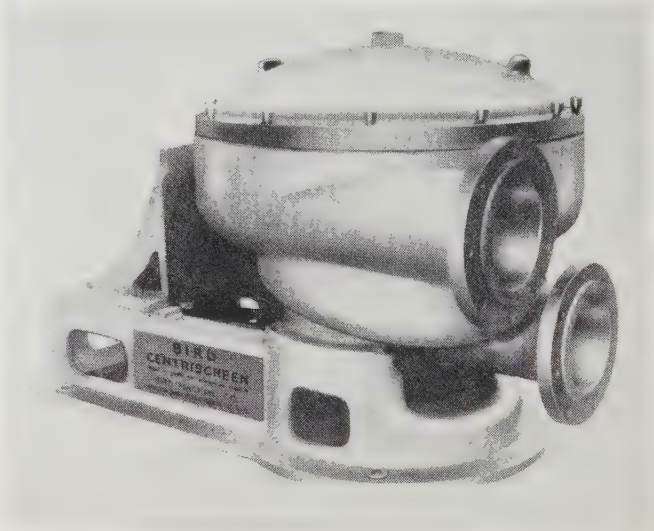
Mr. Peterson joined the company in 1954 as Technical Director. He became assistant mill superintendent the following year. In 1957, Peterson was appointed manager of the Safety Paper division at the Waupaca location, returning to Neenah in that position when the Safety Paper plant was completed here.

James D. Allen, presently Technical Director of Bergstrom has been promoted to the position of bookstock superintendent. In this new position, he will be responsible for the company's pulping operation.

Bird Machine Co.

Model 6 Centriscreen

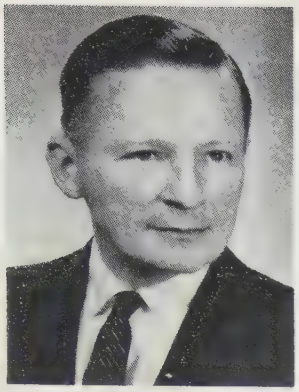
Model 6 Centriscreen, a smaller counterpart of the successful and widely used Model 14 and Model 10 Centriscreens, has been introduced by Bird Machine.



Model 6 Centriscreen

The Model 6 performs identical service for small fourdrinier machines and for a single screen per mold on cylinder machines. Built entirely of stainless steel, the Model 6 Centriscreen is only 30 in. high and 34 in. wide yet it delivers up to 1200 gal. of clean, shive-free stock per min.

Complete information and specifications may be obtained from the Bird Machine Co., home office in South Walpole, Mass., or the regional offices in Evanston, Ill.; Atlanta, Ga.; and Portland, Ore.



E. L. Rastatter, The Bauer Bros. Co.

M. D. Woodruff, The Bauer Bros. Co.

Beloit Eastern Corp.

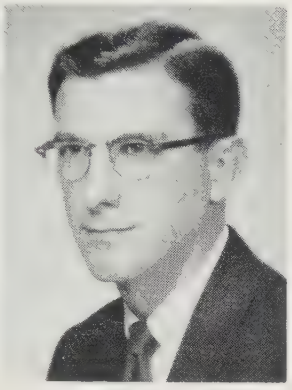
Executives Named

Beloit Eastern appointments are announced by William S. Wood, president, as follows:

B. L. Hammill to sales manager. Mr. Hammill has been associated with Beloit Iron Works for 23 years as engineer, sales engineer, and manager of special products.

W. D. Markowski has been named manager of winder sales. Mr. Markowski has been associated with Beloit Iron Works for five years as a staff engineer and sales engineer.

H. R. Patterson has been appointed chief engineer of the Pennsylvania firm. As a Beloit staff engineer, he has been responsible for some of the major developments in Beloit's finished product processing equipment over the past 10 years.



B. L. Hammill, Beloit Eastern Corp.

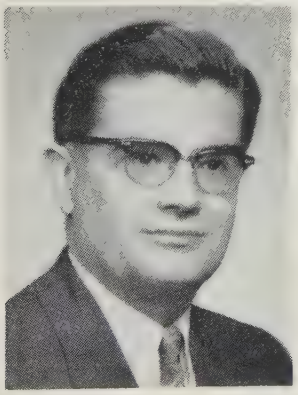
Bendtsen

Three-Tube Tester

Bendtsen is offering its new three-tube tester with a range from 0 to 3000 ml. per. min. Lithograph paper and paperboard as well as a very wide range of other papers can now be tested merely by switching the new changeover cock to feed the airflow through the proper tube without changing the manostat weights.

Hardboard can be measured by ordering a special hardboard smoothness gage.

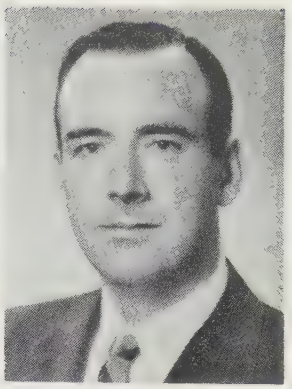
More information from the distributors, Robbins Instrument Co., 110 West 30th St., New York, N. Y.



W. D. Markowski, Beloit Eastern Corp.

H. R. Patterson, Beloit Eastern Corp.

John D. Lynch, Black-Clawson Co.



Robert R. McKellar, Black Clawson Co.

The Black-Clawson Co.

Air Systems Division

The Black-Clawson Air Systems organization is now a full fledged division of The Black-Clawson Co.

Under the joint management of John D. Lynch and Robert R. McKellar, the Air Systems Division with recently expanded engineering and sales staffs, will be fully installed in the Hamilton plant by April 1.

B-C Equipment for U. S. Gypsum

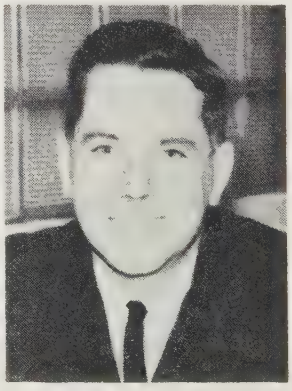
The U. S. Gypsum Co. has awarded a manufacturing contract to The Black-Clawson Co. for all of the major production equipment in the new paper mill U. S. Gypsum is building in Jacksonville, Fla. The mill will produce a range of paper grades for the company's entire line of gypsum board products.

The principal piece of equipment, a 156-in. wide, 9-cylinder paperboard machine for producing 150 tons per 24 hr., will be built at B.-C.'s Paper Machine Division, Watertown, N. Y.

Appointment

Jack A. Perry has been appointed as technical sales service engineer with the Dilts Division of The Black-Clawson Co.

Mr. Perry makes his headquarters at the Dilts plant in Fulton, N. Y. and will specialize in sales and service of Dilts on- and off-machine coating equipment for paper mills and converting plants.



Jack A. Perry

Bowater-Scott Corp.

Burgo Bowater Scott S. p. A.

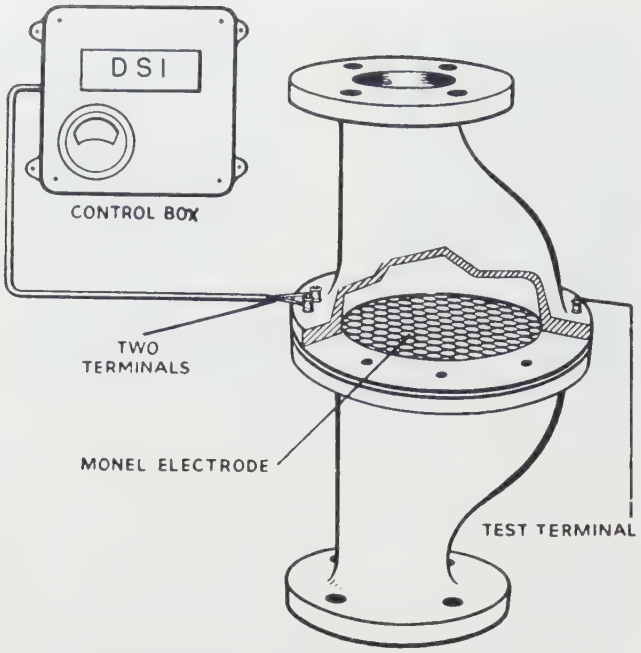
A second European affiliate of Bowater-Scott Corp., Ltd., of England was established in Turin, Italy, on April 7 by the formation of a new company to be known as Burgo Bowater Scott S. p. A. The new organization will be jointly owned by Cartiere Burgo S. p. A., a leading Italian paper manufacturer, and Bowater-Scott.

The Italian company and the British company will have equal representation on the new company's eight-man board of directors with Signor Mansueto Ravizza, board chairman of Cartiere Burgo, serving as board chairman of the newly formed company.

A year ago Bowater-Scott made a similar arrangement with one of Belgium's foremost paper manufacturers, Papeterie de Belgique.

Brandon Sales, Inc.

K. E. Fryfogle, president of Brandon Sales, Inc., Greenville,



The Dehydrosal electrical scale inhibitor components

S. C., and R. Burke Morden, president of Morden Machines Co., Portland, Ore., announce that Brandon Sales, Inc., is arranging to terminate its representation of Morden Machines Co.

Brandon will continue to represent Morden until Morden arranges other suitable representation in the south.

Columbia-Southern Chemical Corp.

$1,000,000 Ethylene Dichloride Plant

Columbia-Southern has begun construction of an ethylene dichloride plant at its Lake Charles, La., facility.

The plant will cost over $1,000,000 and initial production is scheduled for September, 1960. The new unit will adjoin the firm's large chlorine and caustic soda manufacturing operation.

Dehydrosal Systems, Inc.

Electrical Scale Inhibitor

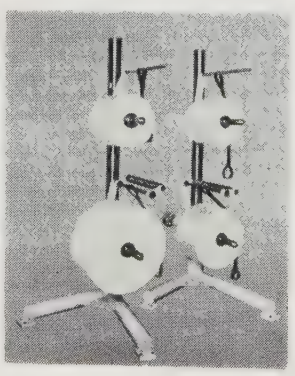
An economical, in-line scale inhibitor, which electrically pretreats hard water, is now available from Dehydrosal. Based on a principle of physical, rather than chemical effect on hard-water salts while they are still in solution, the unit is simple, foolproof, and fully automatic. There are no moving parts and operating expenses are minimal.

The scale prevention device uses electrical energy to alter the normal crystallizing tendencies of the hard water salts—calcium and magnesium—and causes them to precipitate as a fine powdery mass. In steam generation, this material is removed as a soft sludge by a normal blowdown; otherwise, the small crystals pass through suspended in the water.

More information from Dehydrosal Systems, Inc., 521 Fifth Ave., New York, 17, N. Y.

Dietz Machine Works, Inc.

Multiroll Backstand



A cantilever-type, multitier roll stand featuring simplicity of design, rigid construction and compactness has been developed by Dietz Machine Works for use in many paper converting applications. Made to accommodate two or more rolls, one above another, the stand may be used either alone or in combination.

Further details available from Dietz Machine Works, 20 W. Berkley Street, Philadelphia 44, Pa.

Dow Corning Corp.

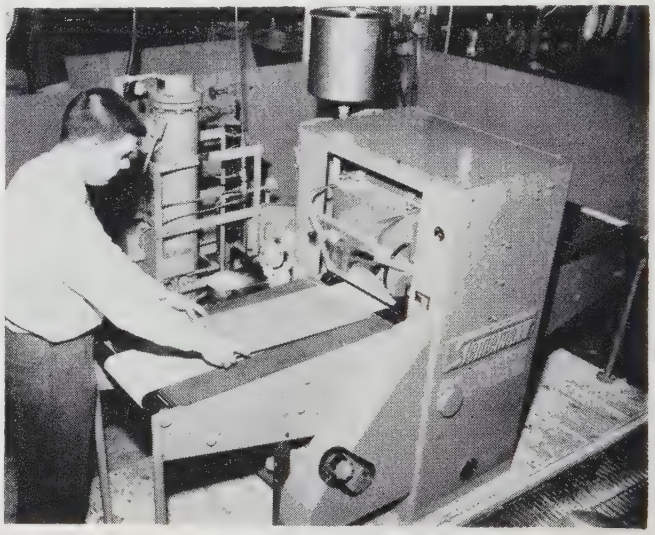
Subsidiaries in Switzerland and Panama

Dow Corning Corp. of Midland, Mich., world's largest manufacturer of silicones, announces the formation of two overseas subsidiaries, Dow Corning A.G., of Basel, Switzerland, and Dow Corning International S.A., of Panama. Dow Corning's president, Dr. W. R. Collings, said today that the moves were being made as steps in the reorganization of Dow Corning's growing foreign business and are designed to facilitate service to its licensees and customers abroad.

Eastman Chemical Products, Inc.

Cut Sheets Melt Coated with Polyethylene

A modified Steinemann curtain coater capable of coating cut sheets of paper and paperboard with low-molecular weight polyethylene was exhibited by Eastman Chemical Products, Inc., subsidiary of Eastman Kodak Co., at the National Packaging Show (Atlantic City, N. J., April 4–7) to demonstrate the application of its Epolene line of resins.



The Steinemann curtain coating machine

Paper stock to be coated is placed on a continuous moving belt, assuring even flow of the stock through the coater as the stock passes through a uniformly thin curtain of polyethylene which is forced under pressure through a finely machined and adjustable slot in the head above.

The thickness of the coating may be controlled by regulating the stock feeding speed, rate of flow of the coating material, head height, and pressure. A trough catches and recycles all material which does not coat the stock, thus completely eliminating waste.

The machine exhibited can coat at any rate between 100 and 950 linear ft per min. It is using a 100% polyethylene coating consisting of 50% Epolene C and 50% Epolene LV.

Frank W. Egan & Co.

Expansion

Frank W. Egan & Co. of South Adamsville Rd., manufacturers of machinery and equipment for the paper coverting, plastics processing, rotogravure printing and textile finishing industries, has announced plans to more-than-double its principal plant facilities.

According to Edward F. Egan, president, an additional 38,000 sq. ft. of working space will be added to the 30,000-sq. ft. building. Construction is expected to begin early this Spring. September is the target month for completion.

Frank W. Egan & Co.

Farrel-Birmingham, Co. Inc.,

T. V. Busk Retires

The company announces the retirement of Theodore V. Busk, advertising manager, under provisions of the company's retirement plan. Mr. Busk's record of continuous service with the company dates from 1916.

The Farrel advertising program continues under the direction of two division advertising managers; Arthur Strahan for the company's products manufactured in Connecticut plants in Ansonia and Derby, and Harry Genzken for lines manufactured in the company's division plants in Rochester and Buffalo, N. Y.

W. R. Grace & Co.

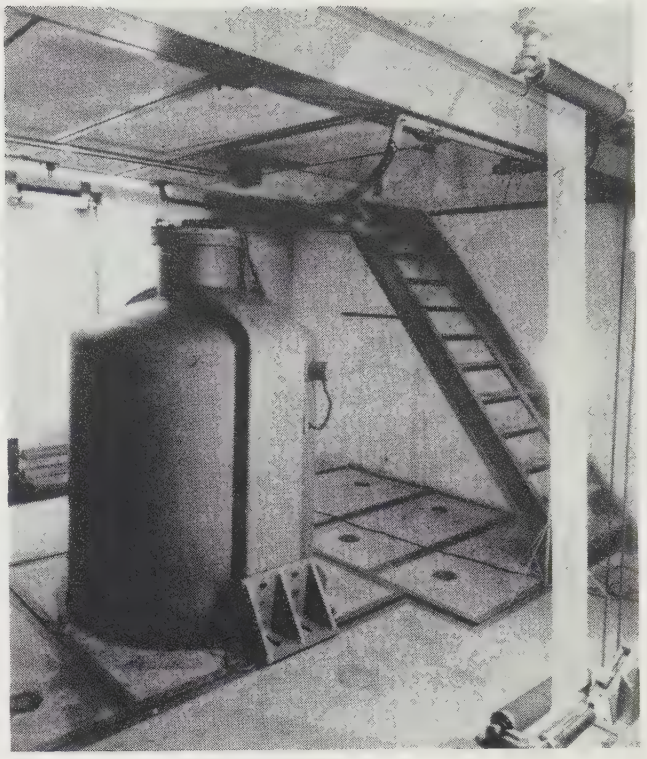
Shrinking Polyethylene Film With High Energy Irradiation

The first commercially successful irradiated plastic film is making possible new types of packaging.

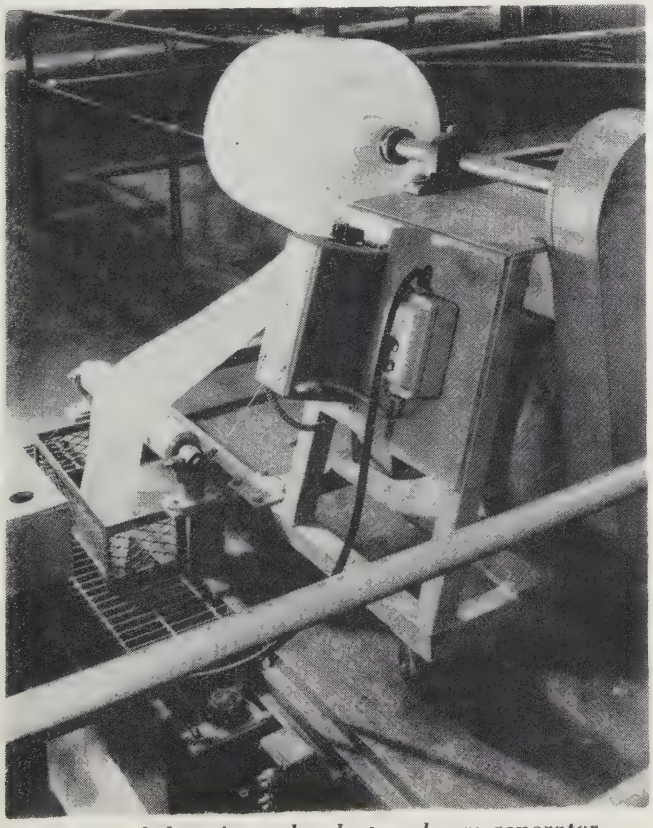
Developed by W. R. Grace & Co.'s Cryovac Division, the basic process employs a G.E. electron beam generator for bombarding polyethylene with up to two million volts. This changes the molecular structure of the polymer and makes possible a new and different plastic film known as Cryovac Type L film, with vastly improved characteristics. One of the most remarkable is its dynamic high-shrink energy.

Especially suited for packaging fruits and vegetables, meat and poultry, bakery and confectionery products, the new film also appears to have a high potential for standard overwrap packaging of many other consumer products in crystal clear skintight contour packages.

This shrink-tight fit, combined with exceptional clarity and gloss imparted in the stretching process and the film's unusual strength (more than six to eight times that of conventional polyethylene) makes for packages that ship well without breakage, and display well regardless of temperature or humidity conditions.



The polyethylene tape passes into the electron beam dome-room

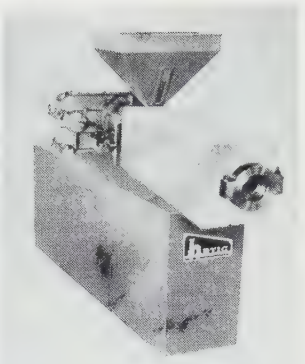


Start of the trip to the electron beam generator

The film takes 4-color printing easily

Hartig Extruders

"Trapezoidal" Extruders Announced



A new series of heavier duty and higher capacity extruders, designed to meet the needs of the newest plastic materials and extrusion technology, is announced by Hartig Extruders, Mountainside, N. J.

Developed to supplement the existing Hartig line, which for many years has been the workhorse of the extrusion industry, the new series features an all new, balanced design, herringbone gear reducer made up of standard gears and bearings assembled in a gear box housing especially designed for the Hartig line. Increased thrust bearing capacity, internal lubrication, higher thermal ratings, and elimination of auxiliary cooling are features of the new gear box design.

More information from Waldron-Hartig Division, Midland-Ross Corp., 1137 Globe Ave., Mountainside, N. J.

Hercules Powder Co.

FDA Approves Pro-fax

Hercules Powder today announced Food and Drug Administration approval of its new plastic, Pro-fax®, for use in products coming into direct contact with all kinds of foods.

The new packaging material which will be described in the Federal Register as "crystalline polypropylene," is Pro-fax 6520 (for film) and Pro-fax 6513 (for injection molding and general purpose extrusion) special food packaging grades of polypropylene produced exclusively by Hercules. It is the first packaging material to win approval through the issuance of a formal Food Additives regulation.

Australia Pty., Ltd.

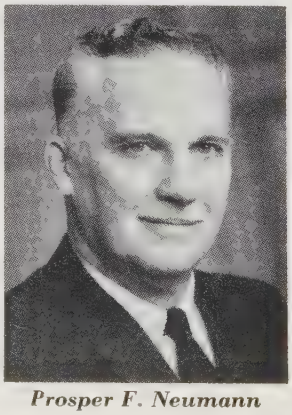
Hercules and A. C. Hatrick, Pty., Ltd., an Australian company, have negotiated an agreement under which they will organize a new jointly owned Australian company, to be known as Hercules Powder Company (Australia) Pty., Ltd.

The new company will provide rosin derivatives and other industrial chemicals for sale in Australia and New Zealand. Headquarters for the new company will be established in Springvale (Melbourne), Victoria.

Swedish Subsidiary

The formation of a wholly owned subsidiary in Sweden, which will build and operate a plant for the production of chemicals for the paper industry, was announced here today by Henry A. Thouron, general manager of Hercules Powder Co.'s International Dept.

Headquarters of the company, Hercules Kemiska Aktiebolog, will be in Gothenburg, and will be headed by Prosper F. Neumann, managing director.



Prosper F. Neumann

The new plant will be designed to produce a complete line of chemicals for the Swedish paper industry. However, at the beginning of operations, production will be devoted entirely to the manufacture of rosin size, both regular and fortified.

Heyden Newport Chemical Corp.

New Tall Oil Plant

Heyden has awarded a contract to Foster Wheeler Corp. to build a 24,000 ton per year tall oil refining plant at Oakdale, La.

The new plant, expected to go on stream early in 1961, will be the corporation's second tall oil plant, converting crude tall oil to higher grade products marketed by the corporation's Newport Industries Co. division, a leading producer of naval stores. The new plant will augment the production of already existing facilities in Bay Minette, Ala., which have a capacity of 36,000 tons per year.

The new Heyden Newport plant will producet all oil rosins, tall oil fatty acids, and distilled tall oils.

Heyden Newport International Corp.

Heyden Newport International Corp., a wholly owned subsidiary of Heyden Newport Chemical Corp., has purchased all the capital stock of N. V. Transicol, a Netherlands' Corporation established at Rotterdam and Geertruidenberg. Transicol is a leading manufacturer of paper size in Holland as well as one of the most important suppliers to the Belgian market.

Hodag Chemical Corp.

Nonionic Surfactants

A bulletin describing the applications and tabulating the properties of 37 representative nonionic surface active chemicals has been published by Hodag.

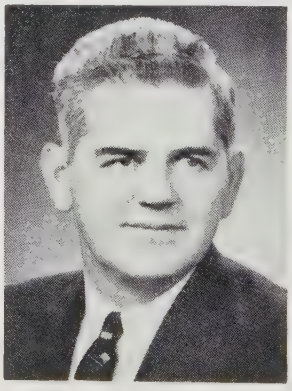
The products are divided into four groups: glycerol esters, other polyhydric alcohol esters, polyglycol esters, and polyoxyethylene alkyl aryl ethers. The new bulletin suggests the considerable variety of chemicals that are available within each of the groups.

Copies of the new bulletin from Hodag Chemical Corp., 7247 North Central Park, Chicago 45, Ill.

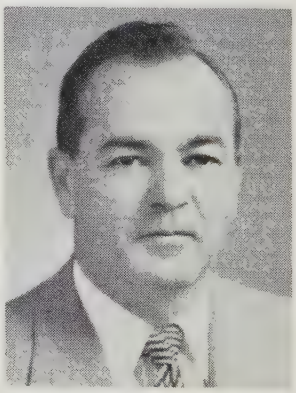
J. M. Huber Corp.

New England Office Moved

The Industrial Products Department of J. M. Huber has moved its New England offices from Boston (Belmont) to 123 Water Street, Watertown, Mass. (phone: Watertown 3–1013). In addition to continuing to serve its rubber and paper industry cutomers in the New England area, the new office offers warehouse facilities for clays, chemicals, and carbon blacks. Vincent Casey continues to head sales of Huber products to the rubber industry, while sales to the paper industry are being handled by Maurice McGrath.



Vincent Casey

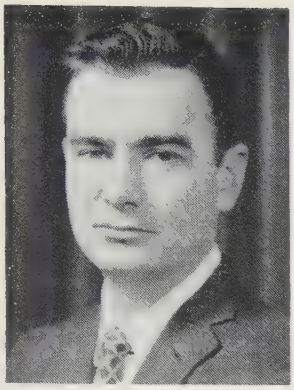


Maurice McGrath

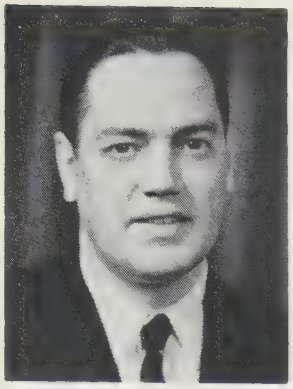
Huyck Corp.

Synthetic Fabric Replacement for Fourdrinier Wire

Development of a new fourdrinier screen has ben announced by the Formex Co., Division of Huyck Corp. The



Sheridan J. McNamara



James B. Northrop

new screen is made of synthetic materials, instead of the bronze wire traditionally used on fourdrinier paper machines

The new product is manufactured under Huyck's U.S. patent 2,903,021.

The fabric, to be marketed under the trade name "Formex," will offer many operating advantages over the traditional metallic fourdrinier wire. Manufactured endless, there is no seam to fill up or hang up on suction boxes. Extremely light in weight and completely flexible, in all directions, it is not subject to damage as a result of wrinkling or creasing during installation or shipping. It is resistant to corrosion in both high and low pH conditions. The elasticity and flexibility of the fabric resists down jams, ridging, etc., caused by wads of paper stock or foreign material dropped on the frabric or caught between the fabric and a roll. Successful commercial trials prove substantial life increase over a conventional metallic fourdrinier wire.

Appointment

Sheridan J. McNamara recently joined Huyck Felt Co., a division of Huyck Corp., Rensselaer, N. Y., as a fluids mechanics engineer in the company's development department. Mr. McNamara was previously employed as Chief Chemist of the West Virginia Pulp and Paper Co. at Luke, Md., where he worked on a variety of pulp and paper projects for more than 3 years.

James B. Northrop has been promoted to assistant to the general manager. Since joining Huyck in 1953, he has served as chief industrial engineer and assistant plant superintendent. His broad experience in all phases of papermakers' felt manufacture has prepared him well for his new assignment.

Hydromatics, Inc.

Corrosion Resistance Rating Guide

A guide listing the relative ability of metals, plastics, and synthetic rubbers used in the manufacture of Flo-Ball valves to resist the corrosive effects of 390 different fluids encountered in industry has been issued by Hydromatics.

Request the corrosion guide from Hydromatics, Inc., Livingston, N. J.

John Inglis Co., Ltd.

Pusey & Jones Assets Purchased

John Inglis Co., Ltd., of Toronto, Canada, has purchased the assets of the Pusey & Jones Corp., paper machinery manufacturers of Wilmington, Del. These assets include patents, trade-marks, the right to use the trade name "Pusey & Jones," drawings, patterns, tooling, jigs, and fixtures, inventories, work-in-process, the widely known Pusey & Jones Plastometer—in fact all assets other than real estate, buildings, and machinery.

The John Inglis Company has manufactured pulp and paper machinery for many years, and since 1945 has been associated with the Pusey & Jones Corp., building paper machines and components in Canada to the Pusey & Jones designs.

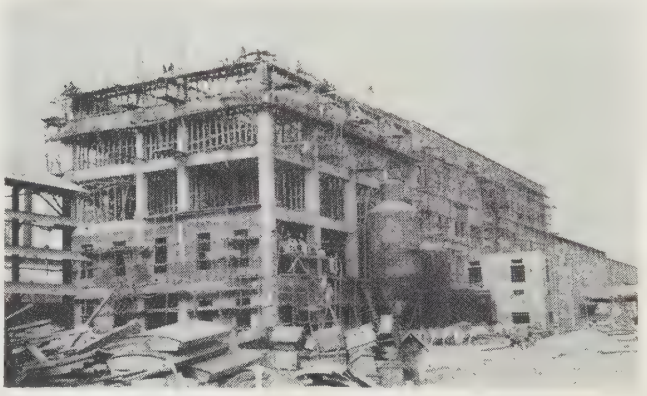
Enquiries should be directed to John Inglis Co., Limited, 14 Strachan Avenue, Toronto, to the attention of Mr. K. S. LeBaron.

Krauss-Maffei-Imperial GmbH & Co.

India

First bagasse pulp mill with pressure cooking goes into production.

The order for design and supply of the first bagasse pulp mill in India was placed with Messrs. Krauss-Maffei-Imperial

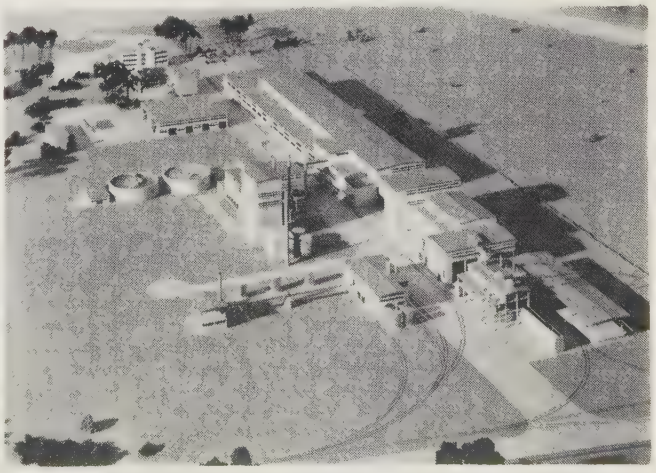


The Shree Gopal Paper Mills, Ltd., Yamuna Nagar, Dist. Ambala, India

GmbH & Co., Munich, West Germany. The associated firm, Krauss-Maffei AG., Munich manufactures the complete machinery and equipment and sends experts to India to help in erecting the plant. The pulp mill for Shree Gopal Paper Mills, Ltd., will be started within a few weeks. The capacity of the mill provides for 25 tons airdry, bleached bamboo pulp to be used for the production of writing and printing papers. At the same time a second production line was provided for a capacity of 40 tons airdry bleached pulp from bamboo or wood.

Egypt

Krauss-Maffei has also completed the design of a pulp mill for Egypt. This mill is designed for a capacity of 80 tons of pulp. Seventy tons will be obtained from rice straw which will be submitted to a special wet cleaning process described by Ernst, Fouad, and Clark in *Tappi* 43, No. 1: 49 (Jan., 1959). Discontinuous digesters were provided as experience in processing rice straw to obtain pulp (on an industrial scale) is rather poor. A second production line for pulp was installed in the same mill with a capacity of 10 tons per day using reed as raw material. Both plants were designed in cooperation with Messrs. Stadler, Hurter, International Ltd.



Pulp and paper mill near Alexandria, Egypt

Manchester Machine Co.

Appointment

Albert (Jack) Peck has been appointed manager of manufacturing and Glenn Williams has been appointed project engineer for Manchester Machine Co., Middletown, Ohio.

Manchester Machine is one of the most rapidly expanding companies in the industry which makes papermaking machinery. The company makes complete machines of the fourdrinier and cylinder types as well as component parts, such as suction rolls and presses, driers, reels, calenders, and winders.

Mercury Chemical Corp.

Methanol-95

Mercury Chemical Corp. announces the commercial acceptance of Methanol-95 as a low cost reducing agent in the chlorine dioxide process for bleaching pulp. The use of Methanol-95 by a present large consumer is resulting in a saving of $18,000 annually, without the installation of additional equipment or modification of the process.

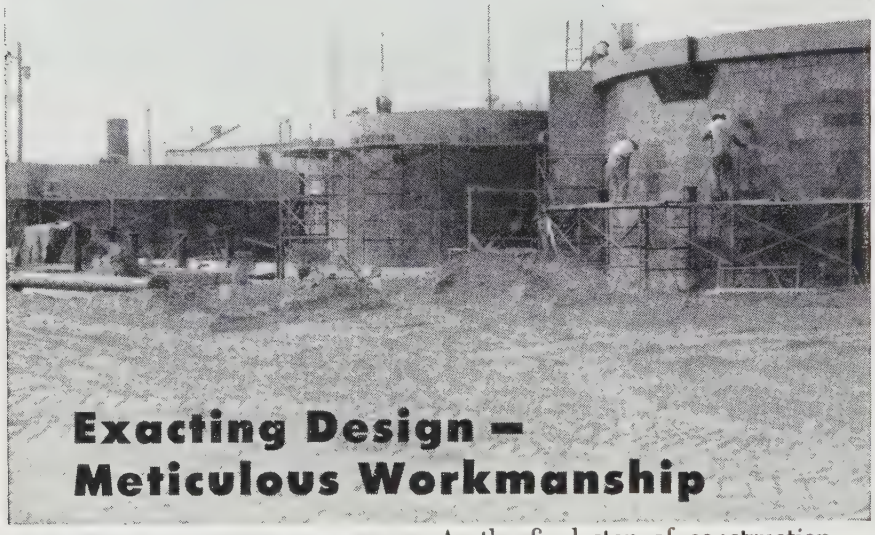
Minor water adjustment through the use of 47% sodium chlorate (rather than 46%) in combination with 60° Bé sulfuric acid and Methanol-95 is suggested.

Minerals and Chemicals Corp. of America

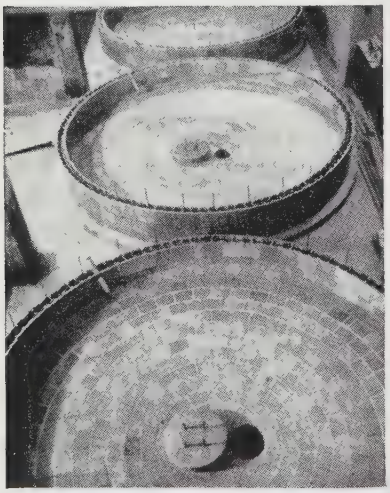
Appointment

Spencer B. Smith has been appointed as a technical sales representative to the paper industry. The appointment extends the company's technical service to the paper industry in the application of its Edgar coating and filling clays.

Attractive, Corrosion-Resistant Glazed-Tile Effluent and Water Treatment Tanks



Exacting Design — Meticulous Workmanship



As the final step of construction, Stebbins workmen carefully wash down the exterior of the tanks with acid.

In this view of tank floors under construction, note the clean, smooth joints — the mark of good workmanship. Note the variety of tile shapes. Horizontal and vertical steel reinforcing is shown in the walls which will be solidly filled with concrete as work progresses.

Complete Service — Design, Installation, Maintenance

WRITE FOR BULLETIN AET-59

SEMCO

STEBBINS Engineering and Manufacturing Company

WATERTOWN, N.Y. • PENSACOLA, FLORIDA

STEBBINS ENGINEERING CORP. — TOWER BLDG., SEATTLE, WASH.

CANADIAN STEBBINS ENGINEERING & MANUFACTURING CO., LTD.

TOWN OF MOUNT ROYAL, MONTREAL 9 • MERCHANT EXCHANGE BLDG., VANCOUVER

SINCE 1884

Specialists in Design, Installation and Servicing of Linings and Tile Tanks

Montrose Paper Mills

Expansion Move

Montrose Paper Mills, converters and distributors of industrial and specialty papers, will move their main offices to a modern new building at 1030 West Chicago Ave. The company will retain their present building at 865 N. Sangamon as a warehouse.

In addition to selling paper in rolls, sheets, bundles, and skids, Montrose is very active as a supplier for the leather goods trade through the manufacture of die cut paper to special shapes as an integral part in luggage, books, and leather products.

Morden Machines

New Advertising Agency

New advertising agency for Morden Machines, Portland manufacturers of stock preparation equipment for the paper-making industry, is Morton and Stanton Advertising of Portland.

First phase of the new Morden program will be market and copy research conducted jointly by Morton and Stanton and Morden Sales and Marketing division. Results of these studies will determine the advertising program for 1960 and 1961.

Morningstar-Paisley, Inc.

Viscosity Stabilizer for Corrugated Box Industry

A new product-information bulletin describing a viscosity stabilizer that drastically reduces the "free water" in paste formulas for corrugated box manufacturing is now available from Morningstar-Paisley, Inc., New York, N. Y. No. 822 viscosity stabilizer is used to maintain proper viscosity despite agitation, pumping, circulation, temperature changes, and starch variations. The product is added at the proportion of only 6 lb. per 333 gal. mix.

The bulletin can be obtained free by writing Morningstar-Paisley, Inc., 630 W. 51st St., New York 19, N. Y.

Nalco Chemical Co.

Robert H. Elkins

Robert H. Elkins

Robert H. Elkins has joined Nalco as manager of corporate research.

Prior to becoming associated with Nalco, Dr. Elkins was associate director of Borg-Warner Research center. His fields of specialization include polymerization, plastics, catalysis, hydrocarbon reactions, petrochemicals, sulfur recovery from hydrogen sulfide, and reactive carbon.

Penick and Ford Ltd., Inc.

Martin for President

M. J. Martin has been named president of Penick & Ford. An executive vice-president since 1957, he succeeds J. M. Widmer, who has retired after 41 years.

Mr. Martin joined Penick & Ford in 1915 in New Orleans and was transferred to New York in 1935. He became vice-president in charge of grocery product sales in 1947 and executive vice-president in 1957. He has been a director since 1952.

Pennsalt Chemical Corp.

Appointments

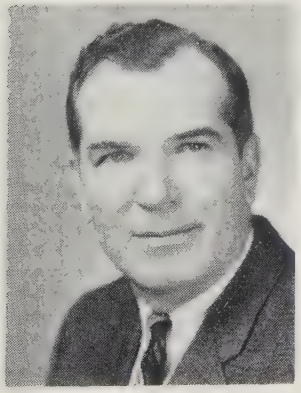
Hugh C. Land, formerly general manager of Pennsalt's Industrial Chemicals Division has been elected a vice-president. Upon the retirement of Fred C. Shanaman as group vice-president, West, on April 27, Mr. Land will succeed Mr. Shanaman and will make his headquarters at Tacoma, Wash. Mr. Land will have jurisdiction over the two western operating divisions, Agricultural Chemicals and Industrial Chemicals-West.

Lee H. Clark, formerly vice-president in charge of administrative services, has been named group vice-president, East, with jurisdiction over the three eastern operating divisions, Chemical Specialties, Industrial Chemicals-East and International.

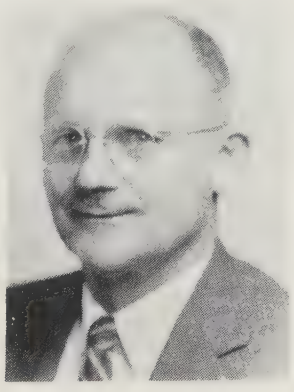
Pure Carbonic Co./Division of Air Reduction Co., Inc.

Carbon Dioxide

A 24-page booklet on CO_2 and its value to industry has just been issued by the Pure Carbonic Co. The illustrated booklet covers the history, principal applications, properties, manufacture, supply and distribution of carbon dioxide in gaseous, liquid, and solid form.



A. Justin Smith, J. O. Ross Engineering

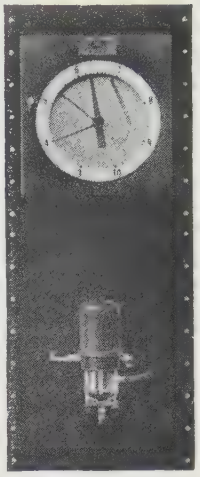


Rolla H. Taylor, Scott Testers, Inc.

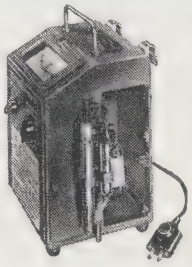
CAMBRIDGE

CONTINUOUS

pH RECORDER



This instrument provides a continuous record of pH in aqueous solutions. Because of its accuracy and dependability, it is extensively used in paper making.



CAMBRIDGE

DIRECT READING

pH METER

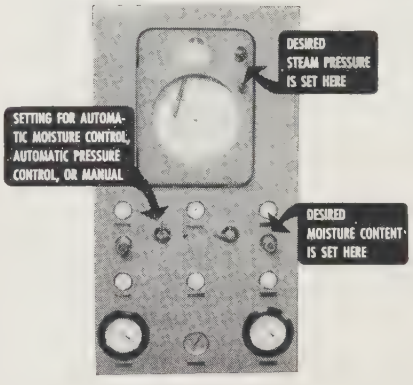
This portable, indicating instrument is especially designed and ruggedly built for plant use. Operating directly from line power, it is so simple to use that unskilled workers can and will use it. Of particular value in processing Pulp, Applying Sizing and Reducing Corrosion of Pipes, Fittings and Equipment.

Send for Descriptive Literature

CAMBRIDGE INSTRUMENT CO., INC.

1620 Graybar Bldg., 420 Lexington Ave., New York 17, N. Y.

PIONEER MANUFACTURERS OF PRECISION INSTRUMENTS


DESIRED STEAM PRESSURE IS SET HERE
SETTING FOR AUTOMATIC MOISTURE CONTROL, AUTOMATIC PRESSURE CONTROL, OR MANUAL
DESIRED MOISTURE CONTENT IS SET HERE

Holds Moisture Content within ½ of 1%

Stickle's Pres-ten-trol is guaranteed to maintain the exact moisture content desired within ½ of 1% automatically—in any type of paper or board, at any machine speed. It records or indicates moisture variation of the sheet, steam pressure in dryers . . . holds pre-set pressure during start-up, wash-up, or wet end breaks . . . restores proper moisture content up to 8 times faster than other controls . . . ends time-consuming hand adjustment of steam flow . . . provides convenient monitoring, with all controls and instruments in one panel . . . cuts steam consumption . . . reduces customer complaints. Get the facts before you buy any system. Write for Bulletin 360-C.

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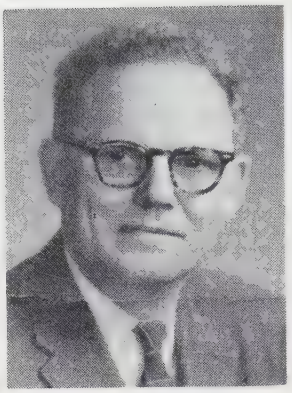
Moisture Control Systems
Dryer Drainage Systems
Feed Water Heaters
Vacuum Pumps
Micro Adjustable Orifices
Differential Control Valves

Stickle Equipment
Cuts the cost of steam

James F. Staley, Southworth Machine Co.



Rudy Meyer, Stadler, Hurter, International, Ltd., Montreal

J. O. Ross Engineering

Appointment

A. Justin Smith, sales engineer for Ross Midwest Fulton Div., Midland-Ross Corp., was recently appointed sales manager for the division.

Mr. Smith joined the Ross Midwest Fulton staff in 1951 and was assigned to the territory of the southern United States.

The Ross Midwest Fulton Division, designs, sells, and services drier drainage and control systems for pulp and paper mills.

Scott Testers, Inc.

Appointment

Rolla H. Taylor has been appointed sales manager for Scott Testers, Inc., Providence, R. I.; manufacturers of a broad line of physical testing equipment. Mr. Taylor has been with Scott since 1953—first as sales engineer, and since 1958, as assistant sales manager. His experience, particularly in the field of elastomeric technology includes some 20 years with the National Bureau of Standards as rubber technologist.

The Smith & Winchester Mfg. Co.

Appointments

The Smith & Winchester Manufacturing Co. announces the addition of five project engineers to their engineering dept.

Waldyn Benbenek is assigned to the electronic dept. working on "Spacemastre" electronic automatic spacer for automation of trimmers.

Gene Rood and Mart Martinson are specializing on Smith & Winchester precision rotary sheeters.

Messrs. C. Rothman and W. Matthews are specializing on "Trimmastre" undercut trimmers.

Southworth Machine Co.

Appointment

Stuart W. Tisdale, president of Southworth Machine Co., Portland, Me., announces the appointment of James F. Staley to resident district manager of paper mill sales for the Mid-West. This territory includes Illinois, Indiana, Minnesota, Upper Michigan, Ohio, and Wisconsin.

Stadler, Hurter & Co.

A. T. Hurter, P.Eng., M.E.I.C., President of Stadler, Hurter International, Ltd., Montreal, consulting engineers, announced recently that Mr. K. R. (Rudy) Meyer, has rejoined Stadler, Hurter & Co. in the capacity of project manager.

Mr. Meyer was formerly assistant chief engineer for the E. B. Eddy Co., Hull, Que., an integrated fine-paper mill of about 500 tons per day capacity.

Before joining the E. B. Eddy Co. in 1949, Mr. Meyer had been associated with Stadler, Hurter & Co. for a 3-year period.

Testing Machines, Inc.

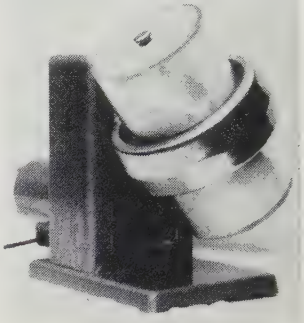
Hinde & Dauch Crush Tester with Dual-Speed Drive

TMI announces the availability of a data sheet illustrating and describing the new Hinde & Dauch crush tester with dual-speed drive.

This tester fills the increasing demand by the paper and corrugated paper industries for a more versatile and flexible Hinde & Dauch crush tester.

For complete literature write to Testing Machines, Inc., 72 Jericho Turnpike, Mineola, N. Y.

The New Rotomixer



A laboratory Rotomixer with mechanical characteristics which insure that not the smallest part of a mix can remain uncompounded. Inside dimensions of the plastic mixing chamber are $6^1/_2$ in. diam. and 12 in. long.

Rotomixer has exceptionally high efficiency because the mixing chamber rotates in two changing planes simultaneously.

The Hunter Carton Scorebend Tester

Literature illustrating and describing the Hunter Carton Scorebend tester is available from TMI.

This simple, accurate test instrument measures the force required to break open flat folded paperboard cartons and thus helps carton manufacturers control production quality and eliminate rejects.

The tester enables users of automatic cartoning machines to specify cartons to a recognized standard and discover "tough" cartons before they can cause filling line slowdowns and stoppages.

KBB Sizing Tester—Automatic Timing

A data sheet illustrating and describing the newly developed automatic timing model of the KBB sizing tester is available from TMI.

The original KBB sizing tester was developed as an answer to the need for a simple, accurate instrument to measure the resistance of paper to water—a widely used principle for sizing determination. In standard models the timing was accomplished manually using a stop watch. The new, improved model handles this very important timing function electronically.

Micro Recording Thickness Profiler

TMI, announces the development of a new machine which combines the latest technology of fine precision thickness measurement with simplicity of design. It is easy to use, easy to check for accuracy, and easy to interpret test results.

Thilmany Pulp and Paper Co.

Stainless Outlasts Carbon Steel

Type 304 stainless steel tubing in the first effect of the black liquor evaporator is reported in excellent condition after 14 years of service.

The stainless tubing has already outlasted the carbon steel it replaced at least 28 times to 1. Carbon steel tubing corroded through in about 6 months.

The Goodyear Tire and Rubber Co.

Appointment

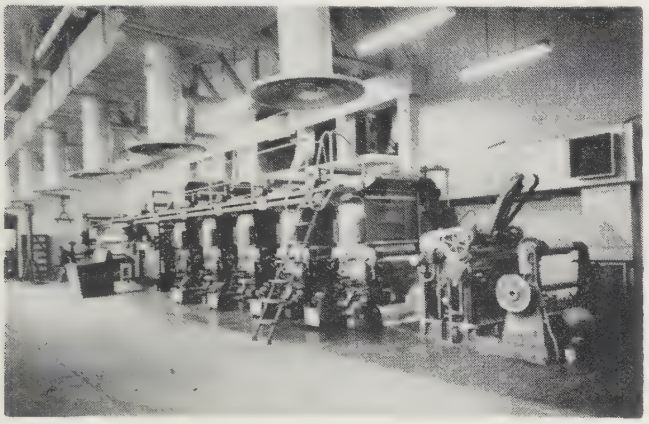
Appointment of George T. Wingate as senior sales representative to the Chemical Division of The Goodyear Tire & Rubber Co. has been announced by C. O. McNeer, division general sales manager.

He will be assigned to the division's Philadelphia district but will cover primarily the Washington, D. C., and Baltimore areas for the division's line of synthetic rubbers, latices, plastics and chemicals.

José Tscherkasky, Sao Paulo

New Cerutti Gravure Press Installed

Installation of a Cerutti "Model 15-R" rotogravure press has recently been completed at the modern new José Tscherkasky converting plant in Sao Paulo, Brazil. A 36-in., 5-color press designed for printing films and other flexible packaging materials, the Cerutti machine is equipped with electronic tension control and flying splicers on both the duplex turnover unwind and surface rewind.



The Cerutti Model 15-R rotogravure press

Visking Co.

Appointment

Howard R. Medici has been appointed chairman and Glen L. Pitzer, president of Visking Co., Chicago, Ill., a division of Union Carbide Corp.

Mr. Medici has been with Visking since 1929 and became president in 1955. Mr. Pitzer was formerly vice-president of Union Carbide Plastics Co.

Visking produces cellulose and plastic food casings used in packaging processed meats and sausages, it also makes polyethylene film.

Walden, Sons & Mott, Inc.

Appointment

S. Overton Mott has been elected a vice-president of Walden, Sons & Mott, Inc., Oradell, N. J., publishers of magazines and catalogs for the printing and paper industries. Mr. Mott's additional duties will cover management of advertising production for *Printing Magazine*'s Metropolitan New York Supplement, a monthly. He also serves as advertising production manager for Paper & Paper Products, tabloid semimonthly.

S. D. Warren Co.

Appointments

Effective February 15, Robert W. Hisey became Chief Engineer of Cumberland Mills, S. D. Warren Co.'s plant in Westbrook, Me. Howard W. Stevens continues as plant engineer.

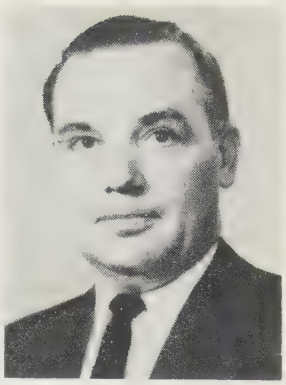
Alfred A. Mann will assume Mr. Hisey's former duties as technical service director.

Western Precipitation Div./Joy Mfg. Co.

New Manager Appointed

Howard W. Lange has been promoted to manager of the western territory of Western Precipitation with headquarters in San Francisco.

Western Precipitation is a leader in the dust and fume control equipment industry, making seven basic types of air cleaning products. The company recently became a division of Joy Manufacturing Company of Pittsburgh.



Howard W. Lange

Westinghouse Electric Corp.

Magnaflow A.-C. Adjustable Speed Drives

A new line of economical, adjustable-speed a.c. drives called Magnaflow, has been introduced by Westinghouse. These drives are of the integral-unit construction, rated from $^1/_4$ to 100 hp. Larger drives with separate motor mounted on a bedplate are offered up to 700 hp. liquid cooled. In addition, simple control modifications to provide a variety of speed operating functions are also available.

More information from Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh, Pa.

Witco Chemical Co., Inc.

Synthetic-Rubber Latex Plant for England

Witco Chemical Co., Ltd., a wholly owned English subsidiary of Witco Chemical Co., Inc., has announced plans for the construction of a synthetic-rubber latex plant at a 20-acre site in the Midlands, England.

On-stream operations are scheduled to begin in early 1961, with an initial annual capacity of 8-million pounds dry weight. The output—a complete line of butadiene-styrene, high styrene, nitrile and other acrylic types of latices—will be sold to the textile, paper, rubber, plastic and allied industries.

General

Thwing-Albert Instrument Co.

Edw. J. Albert, chairman of the board of directors, Thwing-Albert Instrument Co., Philadelphia, Pa., was presented the SAMA Award by the Scientific Apparatus Makers Association, in session for its 42nd annual meeting at Boca Raton, Fla.

Mr. Albert began his business career with Thwing-Albert in 1918. He became President in 1946, a position he held until 1957.

He is a prominent member of the American Society for Testing Materials, a Fellow in the American Association for the Advancement of Science, and a member of the President's Advisory Committee of the Instrument Society of America.

He holds the rank of Colonel (retired) in the Pennsylvania National Guard after 20 years of active service in that organization and is a member of the American Ordnance Association.

Manual on Industrial Water

Second Edition

Executives, plant managers, designers, technologists, and administrators will find in this manual information on the influence of water on industries in which it is used either as a raw material or in conjunction with manufacturing processes.

Standard methods for sampling, analysis, reporting, and testing water, developed by ASTM Committee D-19 on Industrial Water, are included for ready reference, together

with constants, names, and other factors of immediate usefulness to water practitioners. Techniques which have not yet been standardized are discussed to aid the water specialist in keeping abreast of new developments.

Copies of this book may be obtained from ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa., at $11 each.

Dialdehyde Starch and Wet Strength

Research conducted at the U. S. Department of Agriculture laboratory, Peoria, Ill., has shown that wet-end addition of dialdehyde starch to representative pulps under practical conditions has produced papers with excellent wet strengths and improved dry strengths. Handsheets tested had dry breaking lengths of up to 10 km. and retained 30% of this after 30 min. soaking in distilled water.

With dialdehyde starch as a wet-strength additive for paper, broke recovery is easy, wet strength develops rapidly, heating to develop wet strength or accelerate curing is not necessary, and dialdehyde starch dispersions require no aging or curing before use.

"Dialdehyde starch" is a general term for chemicals that are made by oxidizing starch with periodic acid. These starch derivatives have shown promise as raw materials for other chemicals needed in industry, as tanning agents for leather, as industrial binders or cementing agents, and for applications in the textile and paper industries.

Experiments show that additives such as alum materially aid the retention of dialdehyde starch in the pulp. Dialdehyde starch in conjunction with alum produces maximum wet strength in papers when it is applied at pH 4.5. Above this pH wet strength decreases, and varies with the retention of the dialdehyde starch at a pH below 4.5.

Permanency of wet strength in dialdehyde starch-treated paper was determined by TAPPI Standards. At the end of 30 min., the samples retained 22% of their wet strength.

Comparison of treated to untreated handsheets showed that papers containing dialdehyde starch generally have greater dry tensile and dry burst strengths but less dry tear strength.

Sealless "Canned" Pump Solves Sulfurous Acid Pumping Problem at Crown Zellerbach*

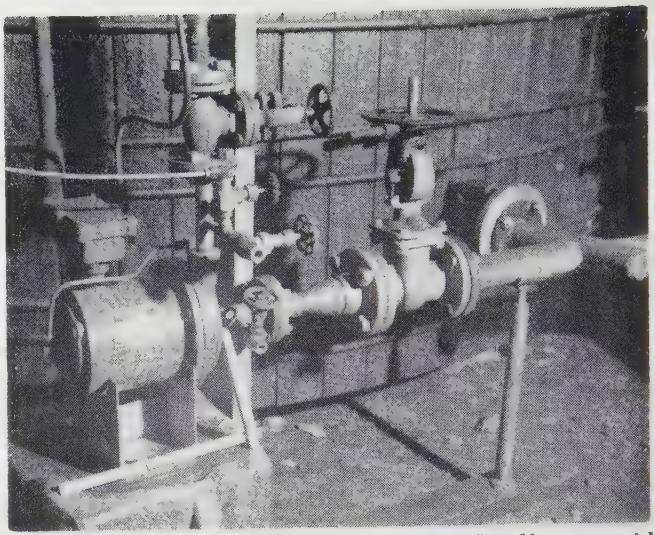
Concentrated sulfurous acid (H_2SO_3) is a highly unstable solution. Any appreciable temperature rise results in the disagreeable liberation of SO_2 gas. Owing to this characteristic, our pumping problem at C. Z., WestLinn, Ore., was especially acute during the summer months.

We were pumping concentrated sulfurous acid (6 to 7% SO_2) from the storage tank at the sulfite mill to the dump chest of our groundwood peroxide bleaching operation in the bleach plant. The acid is pumped for a distance of 800 ft. through a $1^1/_2$-in. plastic pipe to the bleach plant where it is used to neutralize peroxide bleached groundwood pulp after the pulp leaves the reaction tower.

Neutralization is done automatically by a pH indicating and controlling instrument which activates the valve that controls the flow of acid from the pump.

Though it is possible to use conventional centrifugal pumps with water sealed stuffing boxes, the sealing water tends to dilute the acid. Moreover, even with the water seals, there is leakage of the disagreeable SO_2 gas.

* E. J. Roake, Supervisor, Crown Zellerbach Corp., Portland, Ore.



Sealless Chempump handles concentrated sulfurous acid at Crown Zellerbach Corp., West Linn, Ore., paper mill

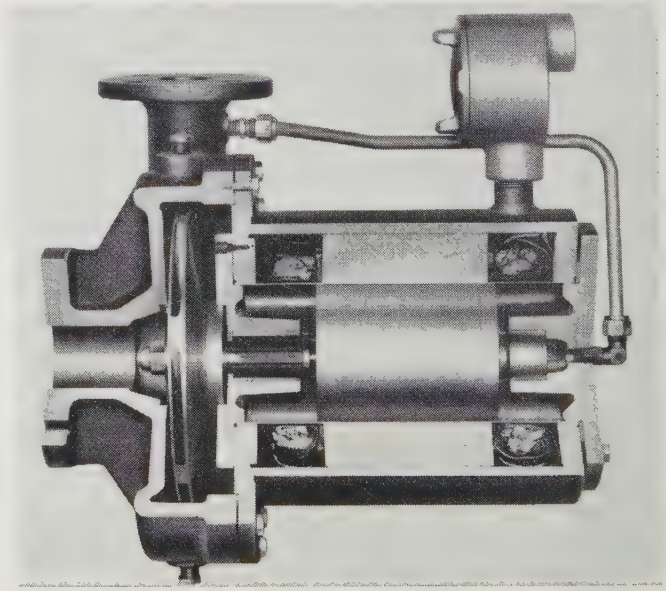
The answer to the problem was found in our installation of a compact sealless "canned" pump made by Chempump Division, Fostoria Corp., Huntingdon Valley, Pa. Due to its unique construction, the sealless pump completely contains the fluid without leakage. Even during the hottest summer months, there is no leakage of objectionable SO_2.

The Chempump, Model CF-$^3/_4$-$^3/_4$ with a capacity of 5 g.p.m. at 30 ft. head, has no stuffing box and requires no mechanical seals (see cutaway view). The rotor is completely enclosed or "canned" in Carpenter 20 stainless steel and forms a single assembly with the shaft and impeller. All wetted parts, including the liner protecting the stator, are also of Carpenter 20 stainless steel.

A portion of the acid circulates through the rotor chamber acting as motor coolant and bearing lubricant. This circulation is achieved by means of a tube which directs a portion of the liquid flow from the pump casing into the rear of the rotor chamber.

Owing to the highly unstable nature of the sulfurous acid, gas locking of the pump at low flows was experienced. However, this difficulty was solved by running a small stream of water over the outside casing of the pump.

The pump has now been in service since 1956, over 3 years, without maintenance of any kind. The stainless steel conventional pumps formerly used required considerable atten-



Cross-sectional view of typical sealless "canned" Chempump, of Chempump Division, Fostoria Corp., Huntingdon Valley, Pa.

tion to packing glands, water seals, and shafts. The pumps had to be completely overhauled on an average of every six months.

Three years of satisfactory service without any maintenance has convinced us that the sealless pump is the solution to our pumping problem.

Packaging Consultants, Inc.

Two well-known research firms, Packaging Consultants, Inc., and Hazleton Laboratories, are collaborating to offer specialized consulting and testing services in the food and drug packaging fields.

Packaging problems which have developed as a result of the recent amendment to the Food and Drug Act are unique in the history of food packaging. The regulations of the Food and Drug Administration are another step toward the protection of the consumer. Programs must be instituted to determine that the packaging materials do not contain harmful ingredients which migrate to the food.

This cooperative program will assist container manufacturers, packaging materials manufacturers, food and drug manufacturers, food packagers, and other affected industries in packaging problems involving the compatibility of the package with food and other items consumed by humans or animals. Specialists of Packaging Consultants, Incorporated are experienced in all phases of design, specification writing, and preparation of technical summaries and trends, and Hazleton Laboratories has facilities for the evaluation of safety in the toxicological, biological, and chemical fields.

Both firms are experienced in the preparation of petitions and other consulting services as may be required in order to meet the new standards of the Food and Drug Administration.

Multiunit "Overland Train"

A new type overland train that rides on 54, 10-ft. high, rubber tires has gone into production, according to an announcement by R. G. LeTourneau, Inc. To be the Army's largest rubber-tired land vehicle, it will consist of 13 cars and be 560 ft. in length.

The multiunit carrier will provide the army with a cargo vehicle capable of operation in remote areas over varied terrain where supply routes are long, fuel supplies limited, and roads nonexistent.

One feature which makes the 13-unit train possible, is the 54 independent-drive wheels, each having a high-torque electric motor geared directly to its rim. Each electric-wheel receives power through flexible electric cables, thus space and length limitations associated with mechanical power trains are virtually eliminated.

Precision tracking ability of trailing cars is demonstrated in "S" maneuver by model of new "overland train" design. Scale model of jeep and driver indicates comparative size of completed logistical cargo train which is being constructed for the Army by R. G. LeTourneau, Inc., of Longview, Texas

OBITUARIES

Marvin Charles Jones

Marvin C. Jones, Midwest representative of the Lockport Felt Co., died on Sept. 29, 1959, in Community Hospital at Battle Creek, Mich., three weeks after undergoing surgery for injuries suffered when a panel truck struck his car on an expressway at Dayton, Ohio, on July 23. The injury appeared to be only minor at the time of the accident. Severe headaches developed later and he entered the Hospital on September 1 for brain surgery from which he never regained consciousness.

Mr. Jones was born in Concord, Mich., on June 16, 1902, and graduated as a chemical engineer from the University of Michigan in 1925. Following graduation he became chemist for Mead Johnson Co., Zeeland, Mich. A year later he joined the Michigan Carton Co. as a chemist where he remained for 22 years as purchasing agent and head of engineering. In 1949 he left to become manager of the Weyerhaeuser Timber Co. mill at Springfield, Ore., for two years before returning to Battle Creek to take a sales position with the Lockport Felt Co.

He is survived by his widow, Martha Brownell, a son Malcolm, two daughters, a sister, a brother and four grandchildren.

Mr. Jones became a member of the Technical Association of the Pulp and Paper Industry in 1927.

Fred Llewelyn Chappell, Jr.

Fred L. Chappell, research chemist for the Paper Makers Chemical Division of the Hercules Powder Co., died at his home in Kalamazoo, Mich., on February 7, 1960, following a heart attack.

Dr. Chappell was born in Kalamazoo, Mich., on Nov. 6, 1902, and received his doctorate from Cornell University in 1933. Following a brief period as chemist for the Sutherland Paper Co. he joined the research organization of the Paper Makers Chemical Division of the Hercules Powder Co. in Kalamazoo.

In his work for Hercules he made outstanding contributions in research on dry rosin size, defoamers, and foaming agents.

Dr. Chappell was a former Chairman of the Kalamazoo Valley Section of the Technical Association of the Pulp and Paper Industry.

John V. Roslund

John V. Roslund, manufacturers' agent, died of cancer in Portland, Ore., on March 1, 1960.

Mr. Roslund was born in Stora Tuna, Sweden, on July 4, 1899, and was educated as a mechanical engineer in Germany. He came to America in 1925 as an engineer for SKF Industries in New York. He joined the Baker Mfg. Co., Saratoga Springs, N. Y., as an engineer in 1927 and the Moore & White Co. in Philadelphia in 1931. In 1938 he joined the sales organization of Asten-Hill Mfg., Co. In 1948 he established his business as a manufacturers agent in Portland, Ore., in which he represented Asten-Hill, H. Waterbury & Sons, and the Dowingtown Mfg. Co.

He is survived by his widow, Rubie M., three sons, John, George, and Sven and two grandchildren. Mr. Roslund was a member of the Technical Association of the Pulp and Paper Industry since 1938.

TAPPI DIVISIONS AND COMMITTEES

Reports of Activities

Project Appropriations Committee

Minutes of the 1960 annual meeting of the Project Appropriations Committee which was held Feb. 25, 1960, in New York, N. Y. Members present: James R. Lientz, Howard S. Gardner, M. S. Kantrowitz, W. C. Bloomquist, John D. Lyall, Abbott Byfield, Joseph J. Thomas, C. R. Calkins, K. G. Chesley, P. E. Nethercut, and John L. Parsons.

Two of the recently appointed members, Messrs. Calkins and Chesley, were introduced to the group. E. O. Ericsson, the third appointee, was absent.

The 1959 annual report of the committee was reviewed. It was the consensus that the procedure followed during 1959 in voting on appropriation requests should be continued this year. By this procedure a preliminary vote is obtained from the committee members and made available to them for their deciding vote.

Mr. Lientz announced that $60,000 was included in the 1960 budget of the Executive Committee for project appropriations. Further requirements will be reviewed by the Executive Committee at its fall meeting.

With the end of 1959, the Project Appropriations Committee marks its 25th year of service to TAPPI. During that time, the total sum of $522,974 has been allocated to Association committees in the form of 142 grants. It was the sense of the Executive Committee, at its Feb. 21, 1960, meeting, that a publication should be prepared to review and appraise the results accomplished during the past 25 years through financing committee projects. It was felt that the training of technical personnel in educational institutions, where many financed projects were carried out, was an important contribution to the paper industry.

Reference was made to the memoranda issued during the past year by P. E. Nethercut on (1) research foundations, (2) TAPPI patent policy, and (3) statement of TAPPI policy on sponsored projects and research programs. Some of these memoranda were in reply to questions raised at the 1959 meeting of the committee.

There was a discussion on ways by which *Tappi* could be made more available to college, university, and other interested libraries. The committee was of the opinion that the results of TAPPI-financed projects were not being distributed as widely as they should be among nonprofit institutions. Dr. Nethercut promised to bring up this subject at a meeting of the Publication Management Committee.

The committee expressed the thought that it might be advantageous for the division chairmen to review the programs of all committees, whether their projects are financed by the Association or not.

John D. Lyall reviewed the high points of the financed projects relating to fiber flow of the Fluid Mechanics Committee at the University of Michigan and the Massachusetts Institute of Technology. Some of the results will be published this year in several articles. Later a monograph on the subject is planned.

JOHN L. PARSONS, *Chairman*

Coating and Graphic Arts Division

TAPPI Monograph Subcommittee—Project 796 (Revision of TAPPI Monographs 8 and 11)

The meeting was held Feb. 24, 1960, for the purpose of reviewing authorship of the various sections for revision of the monographs, and to establish timetable for completion of monograph. Present: George Booth, Nate Millman, Bill Thorndyke, J. Killinger, and Chet Landis.

Items which came before the committee during the meeting and disposition of same were as follows:

1. Discussion of the proposed title which was "Pigmented Coating Processes for Paper & Board." This title was questioned and after some discussion, it was decided that the subcommittee and members of the Coating Council of the Coating Committee would be requested to submit titles for this Monograph to George Booth prior to May 1, 1960, after which the titles received would be presented to TAPPI via Jack Winchester for selection of the most proper title.
2. It was suggested by Chet Landis that wherever waste board appears in the outline, that this be changed to cylinder board. This was unanimously accepted.
3. The committee is targeting to have author acceptance by the Coating Conference in May so that a meeting of the authors can be held during the Coating Conference in May to outline what is expected of them as well as the spirit and objective of this revision.
4. It was decided that manuscripts should be received by Nov. 1, 1960, from the authors selected. This will give them 6 months to prepare their manuscripts.
5. The committee has established a projected date of publishing during the calendar year 1961.
6. It was decided to accept data for the subjects outlined and other suggested changes to the monograph on a provisional basis in that the submission of these data would not insure necessarily its incorporation into the monograph. This decision was reached unanimously in order not to offend those people or companies who submit data in the event the data are not pertinent to the monograph.

G. L. BOOTH

TAPPI Joint Advisory Committee on Printability Research

A meeting of the Joint Advisory Committee on Printability Research was held in New York, N. Y., on Feb. 23, 1960, with the following in attendance:

C. A. Morton, Kimberly-Clark Corp.
W. I. Stinger, Marathon, a Division of American Can Co.
H. W. Verseput, Continental Can Co.
W. A. Bernhardt, Container Corp. of America
C. G. Eckhart, Packaging Corp. of America
H. W. Mackinney, International Business Machines Corp.
F. C. Oppen, Marathon, a Division of American Can Co.
R. J. Quint, Oxford Paper Co.
W. B. Redpath, R. R. Donnelley & Sons Co.
W. L. Rhodes, Rochester Institute of Technology

C. A. Morton, chairman *pro tem.*, opened the meeting with a review of the committee's past activities, for the benefit of the guests present. He called attention to the fact that it is the purpose of this committee to encourage research on subjects relating to printability by the various TAPPI committees.

There followed a review of TAPPI research projects in which the committee has an interest.

Mr. Morton reviewed Project Appropriation No. 130, and its continuation, Project No. 166, on Surface Strength Evaluation Methods, being carried on at Lehigh University. (While this work received its initial impetus prior to the organization of this committee, the committee has a great interest in these projects and in possible sequels to them.) It has been found that temperature variations play a significant part in the poor reproducibility previously reported, and that tack-graded inks remain reasonably stable rheologically for over a year. Tests on production presses have been initiated.

Mr. Morton also reviewed Project Appropriation No. 168 (Transfer and Penetration Aspects of Ink Receptivity), which was a result of this committee's recommendation. The subject of the project is the determination of the factors contributing to the ink receptivity of paper during the letterpress printing of solids, and is being conducted at Lehigh University. The basic plan is to advance the understanding of the ink transfer equation previously developed at Lehigh, through the use of an electronic computer. While only in an early stage, the project is proceeding satisfactorily.

The work on Smoothness and Compressibility of Paper as related to Printability, Project Appropriation No. 167, another project of this committee, was reviewed by H. W. Verseput, chairman of the subcommittee. This work is being carried out at The Institute of Paper Chemistry. Extensive evaluation of the Wink-Van den Akker nip-spreading device has revealed that it is not suitable for the measurement of printing smoothness, mostly because it averages the surface roughness of a relatively large area. An area too small to have an appreciable effect upon the result of such a test could nevertheless have a marked degrading effect upon print quality. The remainder of Project No. 167 will be devoted to an investigation of other means of smoothness measurement, with emphasis upon surface replica techniques.

Discussion of future activities embraced a number of subjects.

Wet Pick: This was defined as picking, in an offset printing operation, in an area which has been wetted or printed in a previous unit, i.e., picking *after* the first impression. The committee agreed that this was a problem of considerable interest and importance, and commended the Graphic Arts Committee on their plan to include this subject as their surface strength project proceeds.

Blistering: This is a closely related subject. It has been defined as body stock failure over an area somewhat more extensive than commonly thought of in terms of "picking." It has been observed in both offset and letterpress, especially where large form areas are involved, and is particularly puzzling when it occurs, not in the first impression, but in a later one. A study of this phenomenon, the committee agreed, should be recommended to the Surface Strength Subcommittee of the Graphic Arts Committee as a logical extension of their work, present and planned.

Curl: Very little is known about the development of curl under the dynamic conditions of tension occurring in modern papermaking and converting processes. Such curl has a serious effect upon the runability of these materials in printing processes. It was decided to refer this matter to the executive secretary for suggestions as to which committee might appropriately undertake a study of this problem.

Heat Blistering: In heat-set letterpress printing, it is often found that paper blisters in the oven. Apparently this is due to vaporization of internal moisture at a rate faster than the resulting vapor can dissipate through the surface, so that internal stresses are set up which exceed the internal bonding strength of the paper. This problem was referred to the Graphic Arts Committee and the Interfiber Bonding Committee for consideration.

Separation Force: The Lithographic Technical Foundation has initiated work in a subject of great potential interest, in their studies on the separation forces involved in the printing process. It was agreed to invite a L.T.F. representative to discuss this subject with the committee. It was also suggested that it might be arranged to hold a future meeting of the committee at L.T.F., thus providing a suitable background for such a discussion.

H. W. Verseput, *Secretary, pro tem.*

Converting and Consuming Division

Plastics Committee

A meeting of the TAPPI Plastics Committee was held at TAPPI Headquarters in New York City on Monday, Feb. 22, 1960, at 2:00 p.m.

The following members and guests were present:

W. N. Stickel, *chairman,* Texon, Inc., South Hadley Falls, Mass.
H. A. Arbit, Union Carbide Plastics, Bound Brook, N. J.
F. J. Banisch, Lowe Paper Co., Ridgefield, N. J.
R. L. Erratt, Dow Chemical Corp., Midland, Mich.
* R. E. Grandpre, Shawinigan Resins Corp., Springfield, Mass.
R. E. Hollinger, Pyroxylin Products, Inc., Pool, Pa.
R. W. Loheed, Charles T. Main, Inc., Boston, Mass.
P. J. McLaughlin, Rohm & Haas, Philadelphia, Pa.
H. G. Maeder, Dixie Cup, Div. of American Can Co., Easton, Pa.
* J. E. Nordgren, Black-Clawson Dilts Div., Fulton, N. Y.
* J. C. Parsell, The J. P. Lewis Co., Beaver Falls, N. Y.
E. J. Paxton, Jr., Continental Can Co., Uncasville, Conn.
* S. R. Phillips, Latex Fiber Industries, Beaver Falls, N. Y.
* G. W. Pixler, Colton Chemical, Cleveland, Ohio
* W. Raas, Waldron-Hartig Div., New Brunswick, N. J.
R. L. Savage, Naugatuck Chemical Div., U. S. Rubber, Naugatuck, Conn.
* B. C. Smith, Naugatuck Chemical Div., U. S. Rubber, Naugatuck, Conn.
V. T. Stannett, College of Forestry, Syracuse 10, N. Y.
R. C. Sturken, Frank W. Egan & Co., Somerville, N. J.
* J. S. Fromton, Frank W. Egan & Co., Somerville, N. J.

The meeting was opened by the chairman, W. N. Stickel.

Project No. 625B—A Fundamental Study of Graft Polymerization of Monomers with Cellulose was first discussed and a

* Guests.

Converting and Consuming Division's Plastics Committee

proposal from the New York State College of Forestry distributed and considered in detail. The proposal was accepted unanimously for submission to the Appropriations Committee through the divisional chairman. H. Arledter, Mead Paper Co. will act as the project subcommittee chairman.

Project No. 784—Resin Identification and Content (R. L. Savage, Naugatuck Co., chairman). The work is nearly completed, but will involve the use of infrared and other techniques. It was agreed that the results of the subcommittee work should be kept in abeyance until release from the various companies concerned has been obtained. This will probably be in May when round robin tests will be run on the various methods proposed to check their accuracy and practicability.

Project No. 785—Internal Bond Test (F. Rosenthal, Knowlton Bros., chairman). The results of the recently conducted questionnaire was presented. It was agreed that two sets of 10 specimens each should be run using the various suggested methods and the results processed on Univac and further Round Robin tests outlined. Texon, Inc., Knowlton Bros., and Latex Fibers Industries will make the original tests.

Project No. 586—Properties of Paper Affecting Adhesion of Resins Used in Extrusion Lamination. This project, which is also of great interest to the Special Paper and Board Affiliates, APPA will be reactivated. J. Thornton, F. W. Egan Co., will investigate the possibility of forming a subcommittee for examination of this question and will report back to the Plastics Committee on his progress at the October meeting.

H. Arbit, Union Carbide Co., will assist Mr. Thornton in this exploratory work. The research proposal on this work which was rejected by the Appropriations Committee as being too general in nature will be redrafted by the new subcommittee when formed.

R. W. Loheed suggested that there should be some correlation of standards and tests with other TAPPI and non-TAPPI committees and will review this matter informally. The progress to date on the progress for the October Plastics-Paper Conference was briefly reviewed by R. W. Loheed, Technical Program Chairman.

The meeting terminated at 3:30 p.m.

V. T. Stannett, *Acting Secretary*

Wet Strength and Interfiber Bonding Committee

Minutes of the Wet Strength and Interfiber Bonding Committee meeting at the Hotel Commodore, New York, on Thursday, Feb., 25, 1960, at 9:00 a.m.

Present at the meeting were:

K. W. Britt, *chairman*, Scott Paper Co., Chester, Pa.
J. W. Eastes, Scott Paper Co., Chester, Pa.
G. I. Keim, Hercules Powder Co., Wilmington, Del.
H. L. Winslow, American Sisalkraft Corp., Attleboro, Mass.
H. J. Kurjan, C. H. Dexter & Sons, Inc., Windsor Locks, Conn.
J. P. Weidner, Container Corp. of America, Brewton, Ala.
V. T. Stannett, State University of New York, Syracuse, N. Y.
R. W. Loheed, Chas. T. Main, Inc., Boston, Mass.
M. L. Cushing, A. E. Staley Mfg. Co., Decatur, Ill.
R. A. A. Hentschel, E. I. du Pont de Nemours & Co., Wilmington, Del.
D. S. Most, Albemarle Paper Mfg. Co., Richmond, Va.
T. J. Drennen, Rohm & Haas, Philadelphia, Pa.
J. D. Robertson, Sonoco Products
P. S. Pinkney, Du Pont, Niagara Falls, N. Y.
J. T. Stearn, Consultant
J. W. Swanson, Institute of Paper Chemistry, Appleton, Wis.
Paul Lagally, Linden Laboratories, State College, Pa.
C. S. Benz, Scott Paper Co., Chester, Pa.
Fred Horowitz, American-Marietta, Newark, Ohio
B. T. Hofreiter, USDA Northern Utiliz Res. & Dev. Div.
G. K. Rauscher, International Paper Co., S. Glens Falls, N. Y.
C. S. Maxwell, American Cyanamid, Stamford, Conn.

Dr. Stannett presented in condensed form an interim report (II) on work carried out at the Forestry College (Syracuse) on TAPPI Research Project No. 118, sponsored by this committee. The subject of their project is "A Study of the Fundamentals of Cure in the Development of Wet Strength Paper." As the data will be published in *Tappi*, no attempt will be made to cover the report in these minutes. The general conclusion is that all evidence indicates that the main mechanism of cure is due to the development of resin to resin bondings rather than resin to cellulose bondings.

John Swanson then discussed the status of TAPPI Research Project No. 161, which is being conducted at The Institute of Paper Chemistry. The subject of this project is "Mechanism of Retention of Wet Strength Resins." Work on this project is continuing, the estimated completion date being Jan. 1, 1961. Current work involves the study of rate of diffusion of the resins to determine whether this factor is the rate-controlling step. Results to date have been conflicting and additional experiments are planned.

A number of color photomicrographs were shown which indicated that wet strength resin is concentrated at the surface of fibers.

Both The Institute of Paper Chemistry and the Forestry College at Syracuse were invited to submit additional proposals for projects that might warrant TAPPI support.

Dr. Stannett was welcomed as a new member of our committee.

A joint session of our committee and the Plastics Committee will be held Oct. 17–19, 1960, at Syracuse. Four papers are desired from our committee, two of which are expected to be from the Institute and Syracuse on the TAPPI sponsored research. Suggestions on additional papers are solicited. Subjects and titles of papers should be ready by May 5, 1960.

During the rest of the meeting Paul Lagally discussed his recently published paper (*Tappi* 42, No. 11, Nov., 1959), entitled "Improved Paper Strength by Active Aluminum Hydroxide." The intriguing possibilities of this approach created a lively discussion.

C. S. Maxwell, *Secretary*

Corrugated Containers Division

Annual Progress Report for 1959

The year 1959 saw each of the five committees of the Corrugated Containers Division grow in varying degrees. Three were very active and well organized; one was hampered somewhat by a change in leadership caused by illness, but shows promise of strength for 1960; and one went through a seedling stage and should now begin to branch out. A detailed report of their activities follows.

The highlight of the year was the functional conference at New Orleans. The Ninth Corrugated Containers Conference drew over 350 participants to the Jung Hotel on Sept. 15–17, 1959. The theme of the technical program was "Engineering Advances and Demands of Modern Packaging." Plant tours were conducted through the Gaylord Container Div. of Crown Zellerbach Corp. at Bogalusa and the Continental Can Co. box plant in New Orleans. J. H. Rooney, Jr., of Continental Can Co. performed very ably as conference chairman.

The Tenth Corrugated Containers Conference is planned for Oct. 10–13, 1960, at the Royal York Hotel in Toronto, Ont. This conference will be jointly sponsored by the TAPPI Corrugated Container Division and the Technical Association of the Canadian Pulp and Paper Association.

Raw Materials Committee

Under the chairmanship of D. C. Shepard, Jr., the committee prepared the technical program for one session of the Ninth Corrugated Containers Conference at New Orleans,

La. The Ink Subcommittee under G. R. Wilmer started a study on ink spreads, but did not develop it into a project because the findings indicated extreme variations. A printing clinic was planned, but was postponed until 1960. The Adhesives Subcommittee under M. L. Hamilton laid plans for preparing an adhesives instruction manual and an adhesives monograph. It is also planning an article for publicizing the importance of efficient adhesive preparation. Project No. 773, titled "Penetration Versus Pin Adhesion and Runability," was begun in an effort to correlate currently available tests with operational performance. Chairman for 1960 is G. R. Wilmer.

Production Committee

The Production Committee under R. W. Buttery completed Project No. 694, titled "Corrugated Box Plant Supervision Survey," and completed the program on Project No. 695, titled "Adhesive Consumption Factors." The latter project is scheduled for completion in 1960. Two other projects were initiated; Project No. 781, titled: "Errors" and Project No. 786, titled "Supervisory Training." These are scheduled for completion in 1961. The former will attempt to classify types of errors and recommend means for eliminating them. The latter will present a course of study with complete lesson plans for a supervisor training course. The committee is also invesitgating types of production control reports now in use. Chairman for 1960 is R. W. Buttery.

Engineering Committee

With R. C. Hutcheson occupying the chair, the Engineering Committee prepared the Technical program for one session of the New Orleans Conference. Project No. 727, titled "Preliminary Survey of Waste Handling Systems," was completed by J. E. Knecht and reported in committee. Project No. 728, titled "Corrugator Roll Life," was completed. Statistics were accumulated for 100 single facers. Valid correlations of wear and physical characteristics or operating conditions could not be drawn, but a comprehensive picture of practices did result. Project No. 729, titled "Roll Standards of Machine Manufacturers," under A. Richardson was rescheduled for completion in 1960 so that information on the new C flute contour could be included. Project No. 730, titled "Basic Considerations for Box Plant Design," under A. H. Fiedler was cancelled when it became apparent that time and personnel were inadequate at this time to treat all the ramifications of the subject. A project, titled "Analysis of the Use of Corrugator Belts," was initiated with J. E. Knecht as project chairman. Completion date is scheduled for December, 1960. Committee chairman for 1960 is R. C. Hutcheson.

Process and Quality Control Committee

Under chairman K. R. Martin, the Process and Quality Control Committee prepared the technical program for three sessions at the Annual Meeting in New York. Project No. 753 titled "Laboratory Equipment Required to Evaluate Component and End Product Quality," was completed. The results were reported to the industry in February. Project No. 752, titled "A Survey of Plant Quality Control Methods," under the leadership of H. I. Stallsmith is determining present industry practices. Project No. 754, titled "Simple Statistical Techniques for the Corrugated Industry," with H. G. Nelson as project chairman will attempt to furnish the corrugating industry a much needed tool. Project No. 762, titled "Fabricating Defects and Remedy Manual," is an ambitious project under H. Donholter scheduled for completion in 1961. Committee chairman for 1960 is H. W. Seibel.

Industrial Engineering Committee

Under W. C. Kline as chairman, this committee defined the scope of industrial engineering in the corrugated box plant and formulated a list of topics for study projects. The committee is planning a membership drive which will enable it to assume the stature commensurate with importance of its function in modern management. T. W. Carroll is committee chairman for 1960.

It is expected that the year 1960 will see further growth in all committees of the division and increasing recognition by the industry of the potential value of this TAPPI Division.

BURT MENDLIN, *Chairman*

Corrugated Containers Councils

A joint meeting of the Corrugated Containers Steering and Advisory Councils was held at the Commodore Hotel, New York City, Feb. 22, 1960. The meeting was attended by the following.

Steering Council:
- B. Mendlin, Cornell Paperboard Products Co.
- J. J. Koenig, Gaylord Container Div., Crown Zellerbach Corp.
- G. R. Wilmer, Packaging Corp. of America
- H. W. Seibel, Gaylord Container Div., Crown Zellerbach Corp.
- R. W. Buttery, Bathurst Containers, Ltd.
- T. W. Carroll, Owens-Illinois Glass Co.
- R. C. Hutcheson, Union Bag-Camp Paper Corp.
- W. P. Blamire, Packaging Corp. of America

Advisory Council:
- R. L. Jenk, Mead Containers, Inc.
- R. D. Merrill, Stone Container Corp.
- P. J. Cox, Consolidated Water Power & Paper Co.
- K. Provo, Gaylord Container Div., Crown Zellerbach Corp.
- H. T. Scordas, Union Bag-Camp Paper Corp.

Special Guests
- D. C. Dowd, Specialty Equipment Corp.
- Bert Joss, Technical Section, CPPA
- H. O. Teeple, TAPPI
- D. M. Davis, Hercules Box Div., Federal Paper Board Co.
- A. Richardson, Gaylord Container Div., Crown Zellerbach Corp.

The meeting was called to order by the Chairman, B. Mendlin, at 2:00 p.m.

Minutes of Previous Meeting. The minutes of the Sept. 15, 1959, joint meeting of the Steering and Advisory Councils were approved as written.

February 1960 Meeting. D. Dowd reported on the status of the three technical sessions scheduled for Feb. 23 and 24, 1960. After a discussion of the speaker evaluation program it was decided that Mr. Dowd could check with the individual speakers, and arrange for this evaluation for those that desired it. Applications for reprints of the papers presented would be available in the meeting room. R. Buttery was to announce the upcoming fall conference in Toronto.

Corrugated Containers' Steering and Advisory Council

Tenth Corrugated Containers Conference. R. Buttery reported that the plans for the Tenth Corrugated Containers Conference in Toronto were progressing rapidly. It is presently planned that committee meetings will be scheduled for Monday, Oct. 10, Technical sessions on Tuesday, Oct. 11, and Wednesday, Oct. 12. Plant tours will be held on Thursday, Oct. 13. An extensive session has been planned by the Printing Ink Subcommittee based on their well-received printing workshop meeting. In order to handle this on the large scale required, a specially prepared motion picture must be made at an estimated cost of $1500. After some discussion, the combined council voted to accept the offer of three suppliers to underwrite the cost of the film.

Reproduction of the technical papers is to be arranged for by H. Teeple and B. Joss in the best possible manner. The cost of this is to be included in the budget and in the registration fee.

Division Progress Reports. (A) The Division Progress Report was prepared by B. Mendlin from the reports of the Committee Chairmen. (B) All committees reported meetings scheduled for 9:00 a.m., Tuesday, Feb. 23, 1960.

February 1961 Meeting. The Engineering Committee will furnish a general chairman for this meeting. It is recommended that the present three-session program be maintained, Tuesday afternoon and all day Wednesday.

The question-and-answer session is not mandatory, but it was pointed out that this has proved to be very popular, and it is a method of bringing the latest developments into the program.

The Industrial Engineering Committee is to handle one technical session, furnishing the moderator and arranging for the papers.

The general chairman is to arrange with H. Teeple for the mailing of the Corrugated Container Division program and other publicity to the Division mailing list in a manner similar to that done for the Fall Conferences.

Eleventh Annual Corrugated Containers Conference. The Eleventh Annual Conference is scheduled for Sept. 11–13, 1961, at the St. Francis Hotel in San Francisco, Calif. H. Wilson has accepted the position of general chairman. O. Wanamaker will serve as technical program chairman and should be invited to meet with the Steering Council at Toronto.

The Production and Engineering Committees are to assist in the preparation of the program and should be ready to report on their progress at the Toronto meeting.

B. Mendlin is to write Wilson and Wanamaker thanking them for accepting their positions and informing them of the part to be played by the committees.

Twelfth Corrugated Containers Conference. The Twelfth Corrugated Containers Conference is scheduled for Oct. 22–25, 1962, at the Statler-Hilton Hotel, Boston, Mass.

J. Koenig is to contact the International Paper Co. to see if they will furnish the general chairman for this meeting.

The Process & Quality Control Committee and the Raw Materials Committee are responsible for the technical program.

Thirteenth Corrugated Containers Conference. The Thirteenth Corrugated Containers Conference is tentatively scheduled for Detroit, Mich., Statler-Hilton Hotel, Oct. 22–25, 1963.

There was much discussion on a proposal by the Testing Division that a joint program on corrugated testing be offered, but it was decided not to accept this proposal. Instead, the program and committee chairmen can work directly with the Container Testing Committee in an effort to get them to present one or more papers at the fall conference.

Technical Operations Committee. B. Mendlin reported that a research fund of $62,000 had been authorized for 1960. In addition, a headquarters fund has been authorized for nonrecurring committee expenses.

Corrugated Containers' Process and Quality Control Committee

It was the belief of the Council that sectionalizing *Tappi* would facilitate the locating of articles related to this industry.

Food & Drug Administration. The Raw Materials Committee was requested to report on the status of the Food & Drug Act as it affects this industry and report to the Council at the fall meeting.

Company Participation. H. Teeple will check the corrugated container attendance lists against the industry list in order to determine what companies might not be participating in this work.

A letter will be sent to selected companies from this list stressing the benefits of participation.

Project Proposal Forms. Revised project proposal forms are available from H. Teeple. It is requested that all committee work be formalized on the project basis.

The meeting was adjourned at 4:30 p.m.

W. P. Blamire, *Secretary*

Process and Quality Control Committee

The meeting was called to order at 9:15 a.m. on Feb. 23, 1960, by Chairman Seibel. The following members were present:

H. W. Seibel, *chairman,* Gaylord Container Corp.
H. E. Dunholter, *vice-chairman,* Eastern Box Co.
S. L. Goodrich, *secretary,* General Box Co.
G. C. Lecky, St. Regis Paper Co., F. J. Kress Box Div.
D. Wolvin, Weyerhauser Co.
N. Varner, Union Bag Corp.
A. Schwartz, David Weber Co.
P. J. Cox, Consolidated Water Power & Paper Co.
F. Albert, Menasha Woodenware
H. G. Nelson, Owens-Illinois
W. B. Lincoln, Jr., Inland Container Corp.
H. Ostrowski, Hinde & Dauch of Canada
D. M. Long, River Raisin Paper Co.
C. A. Turk, Ortman-McCain Co.
J. Corcoran, Packaging Corp. of America
Also B. Jones, Mead Corp., was present as an invited guest.

Mr. Ostrowski, moderator of the 1960 Fall Conference session entitled "New Developments in Packaging," was asked to report on the progress in lining up speakers. In total, five men had been recommended to him, as follows:

1. K. Kellicut, Forest Products Laboratory, "Inner Packing for Fragile Articles."
2. P. Bernard, Hinde & Dauch of Canada, "Frozen Food."
3. R. Mueller, St. Regis, subject "New Developments in Corrugated."
4. R. Petro, Singer Sewing Machine Co., "Special Design Packaging."
5. T. J. Gross, Union Bag Corp., "Bulk Packaging."

Mr. Nelson suggested that John Turk of G.C.M.I. might be contacted to give talk on glass packaging. Mr. Lincoln suggested that Allan Beardsell of Mead Containers might also be added to the list as a speaker on frozen foods.

All the above men will be contacted by Mr. Ostrowski, in order to obtain the acceptance of four. The whole committee urged that the talks be molded into the outline suggested at the last meeting, namely:

1. Fragile articles.
2. Bulk packaging.
3. Displays.
4. Frozen Food packaging.

Chairman Seibel suggested that the category "Frozen Food Packaging" be enlarged to "Corrugated Packs under Refrigeration." Also, the committee urged Mr. Ostrowski to contact the design group for a possible speaker on "Display," seeing that none had been mentioned. Mr. Ostrowski closed his report by stating that he is setting a June 30, 1960, deadline for all speaker's papers.

Mr. Seibel read the resignation of Harvey Stallsmith from both the Committee and Chairman of Project No. 752 "A Survey of Plant Quality Control Methods." Varner, a subcommittee member, was asked to accept the chairmanship. He agreed and was instructed to contact Harvey to check committee progress and keep up continuity. Mr. Ostrowski offered to send a questionnaire that the Canadian group had worked up with the intent of possibly working it into our questionnaire.

Mr. Nelson stated that no reportable progress had been made on Project No. 754 "Manual of Simple Statistical Techniques." He stated that he would be helped greatly by the outcome of project No. 762 under Mr. Dunholter's guidance. The following two persons volunteered to help Henry Nelson's present committee on this very complicated project: G. Lecky and J. Corcoran.

F. Albert, chairman of Project No. 761, "Evaluation of Pin Adhesion Test," was asked to report the progress of his committee. After lengthy discussion, the round robin pin adhesion test program recommended at the last meeting was dropped as a waste of time. Mr. Albert was requested to clarify the original questionnaire and add the following questions:

1. What is the rate of loading?
2. What is minimum average?
3. How did you establish this minimum?
4. Do you run the pin adhesion test under standard conditions?

This revised questionnaire will be resubmitted to the Committee with the results to be discussed at the Fall meeting.

H. Dunholter, Chairman of Project No. 762, "Defect and Remedy Manual," thanked C. Zuzi for his published help in "Paperboard Packaging," December, 1959, on this committee's work. Chairman Dunholter stated that he had obtained assistance from Container Laboratories, Inc. in the form of their published work on defects and remedies. All members of Mr. Dunholter's subcommittee reported on their individual progress. It was obvious that much had been done in obtaining defects and remedies so Chairman Dunholter asked all his committee members to send their information to him by May 30, 1960, in order that he can compile a basic defect-remedy manual and submit it to the whole committee prior to the fall meeting for discussion at that time. The group was then reminded that the completion date of this project was February, 1961.

A. Schwartz, who at the last meeting was requested to report at the present meeting, tentative topics for new projects; did so as follows:

1. Interpretation or test data.
2. Design methods for predicting future results. (So information can be on hand prior to customer receipt of material.)
3. Standardization of sampling technique.
4. Setting up an effective quality control program for an average size box plant. (A suggested follow-up of the quality control equipment questionnaire.)

After a short discussion of these topics it was decided that it would be best to complete several of the present projects before undertaking others. Chairman Seibel instructed the committee to keep these, and any new, topics in mind for deferred discussion at the fall meeting.

Chairman Seibel then brought to the attention of the group, a press release by TAPPI Headquarters that told of the retention of Fuller, Miele, Inc., of New York City, as professional counsel to conduct continuing member relations. The committee was then informed by Chairman Seibel that the process and quality control committee would have the responsibility for one session in the fall meeting of 1962, but as yet no subject has been chosen.

As for other new business, Mr. Nelson suggested that perhaps this committee should start a program that would lead to evaluation of quality control test equipment prior to being put on the market in order to arrive at a uniform machine and test procedure manual, for such equipment and tests.

It was moved that the following names be added to the committee membership: D. Wolvin, J. Corcoran, and C. A. Turk.

The meeting was adjourned at 11:25 a.m.

STANLEY L. GOODRICH

Engineering Committee

A meeting of the Engineering Committee was held in the Hotel Commodore, New York, N. Y. on Feb. 23, 1960. Present were:

N. A. Anderson,* International Paper Co., Whippany, N. J.
R. C. Berger, General Electric Co., Schenectady, N. Y.
R. P. Caponi,* Union Bag-Camp Paper Corp., Savannah, Ga.
W. E. I. Davies, International Paper Co., Whippany, N. J.
D. C. Ellinger, Downing Box Co., Milwaukee, Wis.
W. J. Goettsch, Samuel M. Langston Co., Chicago, Ill.
L. T. Jester,* General Electric Co., Schenectady, N. Y.
Oscar Kleinman, S & S Corrugated Paper Machine Co., Brooklyn, N. Y.
J. E. Knecht, Bathurst Containers Ltd., Whitby, Ont., Canada
T. A. Krawczyk,* Continental Can Co., Teterboro, N. J.
L. W. Kutz, Reliance Electric & Engineering Co., Bala Cynwyd, Pa.
C. B. Lawler,* Union Bag-Camp Paper Corp., Savannah, Ga.
Arthur McKain,* Orthan and McKain Co.
R. D. Merrill, Stone Container Corp., Chicago, Ill.
H. W. Moser, Samuel M. Langston Co., Camden, N. J.
R. L. Newton, Owens Illinois Glass Co., Toledo, Ohio
C. D. Nitchie, Hooper-Swift Co., Glenarm, Md.
C. H. Robson, Lanzit Corrugated Box Co., Chicago, Ill.
A. Richardson, Gaylord Container Corp., St. Louis, Mo.
J. Seliber, Fluid Drive Engineering Co., Wilmette, Ill.
H. F. Thorn, Hooper-Swift Co., Bordentown, N. J.
F. E. Westfall, Lanzit Corrugated Box Co., Chicago, Ill.

1. In the absence of Chairman Hutcheson, the meeting was called to order by Vice-Chairman Richardson at 9:15 a.m.

2. Richardson gave a verbal report on the Steering Council meeting with regard to future meetings.

(a) The Tenth Corrugated Containers Conference will be held at the Royal York Hotel in Toronto, Ontario, Canada, on Oct. 10-13, 1960. Committee meetings will be held on Monday afternoon, technical sessions on Tuesday and Wednesday with plant inspection trips on Thursday.

(b) The Engineering Committee in cooperation with the Industrial Engineering Committee will have joint responsibility for the technical program in connection with the 46th Annual Meeting in February, 1961. Each committee will be responsible for one-half day of formal presentations. A third half day will be allocated for discussions of these papers.

*Guests

(c) The Eleventh Corrugated Containers Conference will be held at the St. Francis Hotel in San Francisco, Calif., on Sept. 11–13, 1961.

(d) The 1962 Fall Conference has been scheduled for Boston, Mass., and tentative arrangements have been made for the 1963 Fall Conference in Detroit, Mich.

3. The minutes of the New Orleans meeting were approved as submitted. Motion by Nitchie, seconded by Westfall.

4. *Report on Takeup Ratio—Project 776.* Mr. Westfall distributed a preliminary report covering about 24 hr. of tests which employed instrumentation furnished by Mr. Moser. The instrumentation for measuring takeup ratio direct, consists of a precision tachometer generator driven by an aluminum wheel in contact with the corrugating medium. This provides a measure of the corrugating medium used. A similar generator on the liner provides information on the amount of liner consumed. A ratio meter combines these two readings and records the takeup ratio direct on a strip chart.

Tests to date indicate there is further work to be done in order to properly correlate and evaluate the use of this instrumentation which was reported to have a selling price of the order of $1500.00. Although no conclusive results can be reported at this time, the tests to date show that the takeup ratio varies from 1.54 to 1.60. The normal range of takeup ratio on "A" flute is considered to be 1.56 to 1.58. It was interesting to note that such things as "slowing down" or "speeding up" do not always cause the same variation in takeup.

Mr. Moser reported that he could find no correlation between needle movement on the ratio meter with changing conditions on the corrugator. Although Mr. Moser's tests were conducted for a limited period of 30 days, he did feel that variables such as caliper, weight, tension, moisture and speed would all affect the takeup ratio.

Mr. Westfall and Mr. Moser plan to continue their investigation in the coming months. Mr. Newton was asked to assist with this study. Plans call for checking and compiling information on the various variables that affect this ratio. The committee hopes that this study will be well along if not entirely completed by the spring Engineering Committee meeting.

5. *Report on "High Temperature Belts".* Mr. Knecht distributed a report covering a survey of heat resistance edge corrugator belts. This report documents the results of a questionnaire which was designed to cover the performance of plain and HR edge belts. Replies were received on the performance of 95 belts of which 61 were plain and 34 were HR. This sampling is small, so the following conclusions are not necessarily applicable to all plants:

(a) Two-thirds of those who changed to HR belts realized an improvement of ten per cent or more in mileage. However, the average mileage and life in months was higher for plain belts than for HR belts, so HR belts are by no means the complete solution to short belt life.

(b) There is a tremendous spread in belt life from shortest to longest. On some corrugators the life is invariably long and on others invariably short. This must be accounted for by operating conditions and care of the belt beyond the factors considered in this survey. It is possible that some of the improvement obtained with HR belts is due to additional care taken of the belt simply because it is a new development. It was agreed that the report on high temperature belts was in excellent shape and that every effort should be made to see that it be included with all of the papers that will be published in connection with the 45th Annual Meeting.

6. Vice-Chairman Richardson expressed the thanks of the committee to the authors of these two project reports. The secretary was asked to send copies of the complete reports to the members of the Engineering Committee who were not present. These will be mailed along with Revision No. 4 of the Committee roster.

7. *Preliminary Plans for the February, 1961 Meeting.* At the request of the Vice-Chairman, the following suggestions were offered as possible subjects for formal presentation:

Mr. Davies: "Materials Handling"—Fork truck vs. cranes for roll handling.
Mr. Knecht: "Adhesive Application"—A report is presently available showing the performance of glue roll drives. Report illustrates the ratio of glue roll speed to sheet speed required to give consistent application from low to high machine speed.
Mr. Newton:
"Cut-off Knife Controls."
"Heating of Single Facer Rolls."
Mr. Nitchie:
"An Evaluation of the Performance of 39 'C' Flute Rolls."
Mr. Goetsch:
"Handling of Heat in the Corrugated Container Industry."
"Metallurgy of Corrugating Rolls."
Mr. Kutz:
"Maintenance Systems and Techniques as Applied to V-S Corrugator Drives."
"Simplicity of V-S Drives Applied to Corrugators."
"Static Corrugator Drives."
"Development of New Super T, V-S Drives."
"Application of Digital Techniques to Knife Accuracy Control."
Mr. Richardson:
"Steam Recovery."
"Materials Handling Techniques."
"Maintenance Costs, Techniques and Training."
"Flexographic Printing."
Mr. Berger:
"Automated Material Control"—as applied to raw materials and finished products, with particular emphasis on identifying, dispatching, storing, recalling and delivering.
"Electrical Methods for Controlling Web Tensions."

After a considerable amount of discussion of these excellent suggestions, Vice-Chairman Richardson made the following assignments:

Mr. Knecht to be responsible for obtaining a speaker on "Adhesive Application."

Mr. Westfall to present a paper on "Takeup Ratio."

Mr. Goetsch to be responsible for obtaining a user speaker on "An Evaluation of the 39 'C' Flute Rolls." Also a user speaker on "An Evaluation of the Langston Knife."

Mr. Nitchie to be responsible for obtaining a user speaker on "An Evaluation of the Hooper Knife."

The committee members assigned should communicate with Mr. Hutcheson on any interim progress between now and our spring meeting.

It was agreed that Mr. Hutcheson be contacted as the committee's first choice to moderate this meeting, with Mr. Richardson as second choice. It was agreed that Messrs. Hutcheson and Richardson would make the final decision in this respect.

8. *Recent Developments by S & S Corrugated Paper Machine Co.* Mr. Kleinman reviewed the progressive development of their type "ZLG" and "ZLM" high speed folder-gluer.

This machine is designed to produce up to 18,000 boxes per hr. Operating experience with the first 33,000-lb. machines prompted a re-design for greater strength. The present "ZLM" folder-gluer weighs approximately 38,000 lb. The front gage steps were also re-designed to improve operation with warped sheets.

These machines incorporate progressive creasing as a standard feature. The primary creasers use a 120°. "V" profile, against a permaflex female, under relatively light pressure. The secondary creasers use a profile-type score against permaflex, under high pressure, thereby providing a well defined folding line. This combination of profiles is analagous to standard metal-forming procedures.

Another major development on these machines includes a box counter in the squaring section. As finished box blanks are underfed into the squaring section, they tend to form a pile that rises from the bottom. At predetermined in-

tervals, two pusher bars mounted on compound chains will push off a pile of boxes. The interval is adjustable for 15, 20, 25, 30, 35, or 40 box blanks. Although it is possible to obtain an average count, an accurate count for each pile is not practical due to variations in paper, folding, warp, etc. To achieve an accurate count, it was necessary to devise a positive means of box separation at the point of pushoff. This was done by adding a pair of screws placed in front of the trailing vertical lift belts in the squaring section. To achieve an equal number of boxes in each pile, these screws are driven at a one to one ratio with the kicker. It is interesting to note that the counting device is not affected by the speed of the machine. In order to improve the efficiency and potential of the folder-gluer, S & S has been working on the development of full width flexographic printing. This unit is designed so that it can be inserted into a standard machine by separating the feed end unit a distance of six feet from the machine's standard folding section. Convenient accessibility to the printing unit, dies and slotter heads is an important feature.

The printing shafts are seven inches in diameter, fitted with antibacklash gears on both ends, so that they can be alternately used as die cutting shafts. Circumferential and lateral running registers are provided. Printing units will be supplied in various widths and they are presently available in 12-, 24-, and 57-in. sizes. S & S expects to have their prototype unit installed in the field within the next 30 days.

Seven-in. wide flexographic printing units are presently operating in the field. They are mounted between slotter heads, in any of the four box panels and can apply color to printing drums placed on the lower slotter shafts. Sectional printers will be available in 7-and 12 in. sizes, thereby making two-color jobs possible when used in conjunction with full width printing units. The printing cylinders are designed for fast setup type of mounting.

S & S expects to provide automatic tying in connection with the folder gluer. There will be a telescoping conveyor in the delivery section, where the piles of counted boxes are discharged. The automatic tyer will be located in a fixed position, unaffected by the squaring section.

Most of these new developments will be compatible with existing machines in the field.

9. *Recent Developments by the S. M. Langston Co.* Mr. Moser reviewed some of the results that have been noted in the field, since Owens Illinois Glass Co. has released the 39 "C" flute for general use by the industry.

42 "C" Flute	*39 "C" Flute*		*Difference*
Flat Crush	49 p.s.i. av.	53 p.s.i. av.	+8½%
Take up ratio	1.45	1.42	+2.2%
Calcd. takeup	...	...	+4%
Runability	Same	Same	
Top to bottom	No data	No data	
Stacking strength furnished since July, 1959	55%	45%	

Mr. Moser announced that their cutoff knife with digital cut length control for both preprinted and nonpreprinted liner had been installed for 30 days at the Container Corporation plant in Dalton, Ill. At the moment, the Langston Co. is still working on machine adjustments.

To date, they have experienced some difficulties with slippage between the double facer pulleys and the belt and between the belt and the paper. Minor troubles have also been experienced with cyclic loads and backlash.

According to Mr. Moser, the sheet length on a standard, well-maintained machine can be held to within $^1/_{16}$ in. With this fact in mind, then the objectives that were established for the digital cut to length control included:

(a) To preselect the length of cut.
(b) To eliminate the need for manual checking of sheet length.
(c) To be compatible with existing knives in the field.
(d) To eliminate the need for electronics.
(e) To provide running register on preprinted liner.
(f) To improve the accuracy of cutoff.

This system uses a correction motor, a power unit and a computer furnished by Reliance Electric and Engineering Co. In addition, a pulse generator in contact with the finished container board provides a measure of sheet passing the of knife. A pulse generator on the knife provides a measure knife position. The computer automatically computes sheet length as a function of the sheet length which is preselected by the operator. A web scanner is also provided to scan one mark per cut when used with preprinted liner.

The prototype model employed transistors in the computer; however, the high ambient temperatures caused the transistors to fail. Therefore it was necessary to redesign the computer with electronic tubes.

At the moment, this installation is in its final stages of debugging. At the moment, results indicate that it is possible to hold cut length to within plus or minus $^3/_{64}$ in. at all speeds up to 450 f.p.m. and lengths up to 60 in. After final tuneup, Mr. Moser expects that this knife will be able to hold the length of cut to within $\pm^1/_{32}$ in. at speeds up to 600 f.p.m.—a 50% improvement over conventional knives.

10. Vice-Chairman Richardson thanked Messrs. Kleinman and Moser for their reports on recent developments within their respective companies.

11. *Spring Meeting.* After a short discussion, it was decided to hold the annual spring committee meeting on Tuesday, May 10, 1960, at the Pittsburgh Airport Hotel at 9:00 a.m.

12. *1960 Projects.* Vice-Chairman Richardson asked for suggestions from the floor for possible projects to be pursued in 1960.

Mr. Knecht:
"Methods for calculating the payoff period for capital equipment."
"Ward Leonard adjustable-speed drive systems and their effect on power factor."
"Amount and use of maintenance records."
"Automating office procedures—data processing."
Mr. Davies:
"Basic study of the moisture content in the medium and liner in all phases of manufacture from roll stock to finished product."
"Electric inspection of glue pattern by resistance measurement."

Meeting adjourned at 12:15 p.m.

R. C. Berger, *Secretary*

Production Committee

R. W. Buttery—*chairman,* Bathhurst Containers, Montreal, P. Q.
D. Blackburn—*vice-chairman,* Martin Paper Products, Ltd., Winnipeg, Kan.
K. Provo, Gaylord Container Corp., Div. of Crown Zellerbach, St. Louis, Mo.
J. Simpson, St. Regis Paper Co., Cleveland Corrugated Box Div., Cleveland, Ohio
D. Kaley, Union Bag—Camp Paper Corp., Savannah, Ga.
D. C. Dowd, Specialty Equipment Corp., Worcester, Mass.
S. Johnson, Continental Can Co., Toronto, Ont.
D. J. Jordan, Hygrade Containers, Montreal, P. Q.
J. D. B. Howard, Bathhurst Containers, Ltd., Montreal, P. Q.
W. J. Hurrell, Hinde and Dauch Paper Co., Etobicoke, Ont.
F. Glass, Green Bay Box Co., Green Bay, Wis.
B. Mendlin, Cornell Paperboard Products Co., Milwaukee, Wis.
D. Adams, St. Regis Paper Co., Canton Corrugated Box Div., Canton, Ohio
H. W. Wilson, Royal Container Co., San Francisco, Calif.
R. W. Catzen, Baltimore Paper Box Co., Balitmore, Ohio
A. C. Reid, Pembroke Shook Mills, Ltd., Pembroke, Ont.
T. Monaghan, Sherbrooke Paper Products

1. The meeting was called to order by Chairman Ralph Buttery at 9:00 a.m. Feb. 23, 1960 in Room 1048 of the Commodore Hotel. In the absence of Secretary Loren Ash-

wood. Burt Mendlin circulated the attendance record sheet and took minutes.

2. *Project No. 695* was reported on by Project Leader Blackburn. Data is being received. Results from the University of Manitoba are expected in 30 to 40 days. Each contributing plant will receive its results immediately. A composite report will be submitted to the committee at the Toronto meeting in October.

3. *Project No. 786* was reported on by Mr. Mendlin in the absence of Project Leader Ashwood. Four lesson plans have been completed: Communications, Human Relations, Handling Grievances, and Methods. These were circulated in advance of the meeting so that they could be criticized at the meeting. The committee agreed that they were excellent and represented a great deal of effort. To lighten the load of the Project Committee in assembling the remainder of the lesson plans, members volunteered to work up the remaining lessons plans and send them to Messrs. Ashwood, Williams, and Mendlin by the end of July. The following assignments were accepted:

Costs—J. Jordon
Union contract—S. Johnson
Errors—W. Hurrell
Safety—D. Adams and J. Simpson
Quality—K. Provo
Waste—D. Keley
Company policy—R. Catzen

The project committee will modify these lesson plans as they see fit and present the package of eleven to the committee at Toronto.

The committee felt that no presentation of the lessons plans should be made until the course was complete and deferred decision on the form in which they should be presented to the industry.

4. *Project No. 781* was reported on by Project Leader W. Hurrell. Mr. Hurrell circulated a draft of a questionnaire on errors and a discussion of the questionnaire followed. Mr. Mendlin suggested the addition of a question or two on the amount of customer credit issued so that there would be some basis of comparison of individual plant to average or mean. Each committee member is to fill out the questionnaire and return it to Mr. Hurrell together with his recommendations for changes in the questionnaire. It was the concensus of opinion that the valid conclusions from this study should be presented in the form of a paper at one of our meetings rather than circulate the questionnaire to the industry.

5. Mr. Provo reported that he had collected and distributed the production control forms in use by various plants. A discussion followed which demonstrated a considerable range of thinking on what production control figures were most useful. A subcommittee was set up consisting of Messrs. Provo, Kaley, and Adams with Mr. Provo as chairman. This committee is to prepare three lists of desired production control information, daily, weekly, and monthly. The information is that needed by a plant manager or superintendent to keep his finger on the pulse of his operation. F. Ashwood will obtain a project number for this study.

6. D. C. Dowd reported everything in order for the February, 1960 technical program. Chairman Buttery thanked Mr. Dowd for taking over this assignment and doing an excellent job when Mr. Bowers was obliged to withdraw because of pressure of company obligations.

7. Mr. Buttery reported on the October, 1960 conference at Toronto. This will be jointly sponsored by TAPPI and the CPPA Technical Section. The Production Committee further shares the technical program with the Raw Materials Committee. The technical program will be held on Tuesday and Wednesday, October 11 and 12 with committee meetings on Monday and Plant Tours on Thursday.

8. A duscussion was held on committee membership. It was concluded that anyone who has attended any of three previous meetings should be considered an active member. Chairman Buttery shall informally contact anyone previously active who has not been at one of the three previous meetings and obtain an expression from them as to whether they wish to remain active.

9. Under new projects, Mr. Glass raised some questions about supervisory practices. He will present his thinking on project work in this field after studying Mr. Buttery's paper summarizing Project No. 694. Chairman Buttery asked all committee members to send him recommendations by mail for new projects.

10. The Production Committee has responsibility for part of the technical program at San Francisco in September, 1961. Chairman Buttery appointed Messrs Kaley and Catzen as moderators.

11. Chairman Buttery appointed a nominating committee of Messrs. Dowd, Hurrell, and Kaley to present a slate of officers for 1961 at the 1960 Fall meeting at Toronto.

12. The meeting was adjourned at noon.

Burt Mendlin, *Acting Secretary*

Engineering Division

Chemical Engineering Committee

A meeting of the Engineering Committee was held ot the Hotel Commodore, New York, N. Y. on Feb. 23, 1960. Present were:

Members:

A. W. Plummer, *chairman*
John Lewis, *vice-president*
R. F. Clemens, *secretary*
E. C. Bowen
Lyle C. Jenness
Charles W. Carroll
J. H. Hull
H. L. Warner
E. F. Thode
J. E. Vivian
Roy P. Whitney
Andrew J. Chase
Joseph L. McCarthy

Guests:

R. H. Bernstein—Chas T. Main, Boston, Mass.
L. Johanson—University of Washington, Seattle, Wash.
W. G. Meyer—Crown-Zellerbach Corp., Camas, Wash.
Stuart R. Cooper—Oxford Paper Co., Rumford, Me.
D. J. Morrissey—Trimbey Machines, Inc., Glens Falls, N. Y.

Chairman Plummer opened this informal luncheon meeting outlining the Committee's objective of a program that would require more activities for all members. Also, the committee will investigate the feasibility of an interim meeting between national meetings where we will not have the distraction of other meeting activities.

John Lewis, our new Vice-Chairman, was introduced.

Mr. Plummer briefly outlined the work of the following subcommittees.

Data Sheet Committee—Headed by A. J. Chase. Data not found in standard handbooks is solicited with the eventual objective of publishing a special handbook.

Publicity—Handled by R. F. Clemens. Thus far this activity has been confined to *Tappi* magazine newsletters and releases on committee personnel.

Engineering Problems Committee Project No. 780—Headed by L. C. Jenness. Problems are being solicited from members and member companies by letters issued by J. R. Lientz and H. O. Teeple. Thus far, ten problems have been received with promise of several more.

Liaison Committee—Headed by E. C. Bowen. This committee has to do with our overlapping interests with other TAPPI committees.

Operation Research and Systems Engineering—Headed by

E. F. Thode. This committee has been very active presenting papers at recent meetings and a full program is scheduled for the Jacksonville Meeting. It appears likely that some of the activities of this committee will be the basis for a new full TAPPI committee. Dr. Thode will report on a basis for initiating this step.

Dr. Jenness commented on the high regard TAPPI holds for our chemical engineering problems program as evidenced by letters issued by Messrs. Lientz and Teeple soliciting problems from industry.

Dr. Thode announced an open meeting on Operations Research with APPA people directly following this meeting. All members were invited.

Mr. Chase requested data sheets from all, particularly of a chemical engineering nature. Mr. Clemens was requested to submit a list of members for Mr. Chase to assign jobs on these data sheets.

Dr. McCarthy moved that our chairman consider holding a formal meeting at our annual TAPPI Meeting either as a luncheon meeting or at some other suitable period. This motion was seconded by Mr. Bowen. This suggestion was submitted as an alternate to an interim meering.

Dr. Jenness mentioned that the Engineering Problem Subcommittee would hold a meeting on Thursday, February 25.

Meeting adjourned about 1:45 p.m.

R. F. Clemens, *Secretary*

Chemical Engineering Subcommittee (Project No. 780)

This subcommittee met at the Commodore Hotel, New York City, on Feb. 25, 1960, with Chairman Jenness presiding.

Members present: J. H. Brown, Johanson, R. C. Paris, and L. C. Jenness, *chairman*.

Guest: M. A. Burnston, TAPPI.

Copies of 20 problems, with solutions for most of them, were available for distribution. These were discussed from the standpoint of desirability and disposition with regard to editing and classification.

It was agreed that all 20 of these problems would be suitable after minor changes of statement and checking of solutions. Some solutions remain to be received.

Mr. Johnson agreed to edit those problems already available in the fields of stoichiometry, kinetics, and thermodynamics, and was given a complete set of problems.

Mr. Brown agreed to edit problems already available in the fields of evaporation and economics and was given a complete set of problems.

It was further agreed that the chairman should solicit other individuals to edit problems in the remainder of ten fields and received several suggestions for such editors. If you would serve in such a capacity or know of other qualified persons, the chairman would appreciate such notification.

Another publicity article to appear in *Tappi* was discussed, constituting an appeal for more problems from industry, and that article has been published. It was reported that the response from industry up to that time was discouraging in that very few concise chemical engineering problems had been forthcoming.

The matter of a summer meeting of the subcommittee was discussed and such a meeting is now being contemplated for the month of July. In the meantime seven more good problems have been received and others have been promised.

Civil Engineering Committee

The Civil Engineering Committee of the Engineering Division of TAPPI met at the Commodore Hotel, New York, N. Y., March 16, 1960, at 12:30 to 2:00 p.m.

Present: W. Pittam, L. L. Wallace, B. M. Center, C. E. Bouis, G. M. Campbell, J. W. Crawford.

Absent: J. Beaver, J. H. Bringhurst, R. A. Jackson, G. E. Smith.

The Fifteenth Engineering Conference in Jacksonville was discussed and it was decided that Mr. Pittam would deliver a paper on "outfall lines into large bodies of water." Mr. Pittam also has another man in mind whom he is going to contact on a paper in regard to building foundations. Another idea was a panel discussion on building roofs. As program chairman, Mr. Pittam will investigate this possibility also.

A brief discussion on TAPPI Data Sheets Nos. 79, 89, and 90 was followed with the conclusion that all members should submit a report on these sheets by June 1, 1960.

Project No. 787 regarding reference books considered as a standard was briefly discussed and those members who had not turned in their lists were urged to do so, so that we can review it again at Jacksonville.

The next order of business was the change of the name of the committee and, after a brief discussion, Mr. Center moved that the name of the Civil Engineering Committee be changed to "The Construction Committee," with the activities of the committee remaining the same. This motion was seconded by Mr. Wallace. The motion was carried unanimously.

The proposed recruiting letter for prospective members was reviewed by the committee and met with their approval.

The meeting was adjourned by the chairman at 2:00 p.m.

C. Elliott Bouis, *Secretary*

Drying Committee

A meeting of the Drying Committee was held at the Hotel Commodore, New York, N. Y. on Feb. 23, 1960.

Present were:

Members

S. G. Holt, Consolidated Water Power & Paper Co.—*chairman*
G. E. Jackson, Bowaters Southern Paper Corp.—*vice-chairman*
K. K. Khandelwal, Beloit Iron Works—*secretary*
L. R. Blomgren, American SF Products, Inc.
G. H. Cash, Mead Corp.
F. L. Cessna, Sorg Paper Co.
A. J. Cirrito, Rice Barton Corp.
H. P. Fishwick, Mason-Neilan Regulator Co.
W. A. Green, Manchester Board & Paper Co.
L. G. Janett, J. O. Ross Engineering Corp. (represented by W. K. Metcalfe)
J. J. Kilian, West Virginia Pulp & Paper Co.
G. Krikorian, Rice Barton Corp.
J. M. Mallory, Union Bag-Camp Corp. (represented by J. L. Idleman)
D. F. Pohlman, Scott Paper Co.
F. G. Perry, Arthur D. Little, Inc.
N. M. Reitzel, West Virginia Pulp & Paper Co.
R. C. Swaney, Carlisle, Pa.
L. R. Vianey, Eaton-Dikeman Co.
R. E. White, Villanova University
S. C. Williams, Dominion Engineering Works, Ltd.

Guests

W. J. Antonachio, American Gas Association
C. D. Bast, Black Clawson Co., Inc.

Members Absent

R. M. Cook, Ross Midwest Fulton Corp.
E. G. Drew, Drew Engineering Co.
W. F. Overly, Overly's, Inc.
R. A. Paramore, Central Fibre Products Co.
R. C. Portouw, Drew Engineering Co.

The meeting was called to order at 12:45 p.m. after luncheon by S. G. Holt, chairman. The minutes of the previous meeting were approved.

William Antonachio of American Gas Association was introduced along with C. D. Bast of the Black Clawson Co., Inc.

Session on Feb. 25, 1960 will be held under the chairmanship of S. G. Holt and three papers will be presented by the following authors: Horace L. Smith, R. A. Hurm of Beloit, and A. H. Nissan and D. Hansen of Rensselaer Polytechnic Institute.

R. C. Swaney and L. R. Vianey were assigned responsibility for the operation of the slide projector and distribution of reprints.

Fred Perry stated that Dr. Nissan had presented a very interesting paper at the last SIUE Meeting in San Francisco. It was suggested that it would possibly be a good paper for him to repeat at a TAPPI meeting.

Minutes of the last meeting were discussed and approved after one correction: Joe Killian's name is to be replaced by Lu Vianey on Project 757 Subcommittee.

Fifteenth TAPPI Engineering Conference, Jacksonville, Fla. The outline for radiant heat drying symposium at Jacksonville meeting was presented. This program is being sponsored by the American Gas Association and the following outline was suggested for the one-half day session, "Radiant Heating—Its Characteristics, Generation, and Application."

Radiant Heating—Its Characteristics, Generation, and Application

I. Introduction
   - A. To review the meaning of radiant heat and its characteristics.
   - B. To inform the audiences of the methods and available equipment for the production of radiant heat energy.
   - C. To relate the benefits and advantages of radiant heating to the processes of the paper industry.

II. A. Radiant Energy Defined
   1. Electromagnetic radiation and location of infrared on spectrum by wavelength.
   2. Effect of temperature on production of:
      (a) Near infrared—0.7 to 3.0 μ.
      (b) Far infrared—3.0 to 400 μ.
   3. Effects of temperature, color, and surface smoothness on:
      (a) Absorptivity.
      (b) Emissivity (vital to show that effective emissivity involves emitter and receiver characteristics, shapes, and sizes).
      (c) Reflectivity of infrared.
   4. Nature and determination of heat exchange by radiation.

   B. Sources of Radiant Energy
   1. Sun and any other body.
   2. Production of infrared by electric means—advantages and disadvantages of each.
      (a) Bulbs or lamps.
      (b) Strip heaters.
   3. Gas as a fuel.
      Natural or LPG (discuss heating values).
   4. Gas burners and infrared generators.
      (a) Types.
         (1) Low temperature 850′—metal.
         (2) Medium temperature 1800′—Ceramic; metal plates and tubes; wires.
         (3) High temperature to 2500′—Ceramic tubes and other shapes.
      (b) Capacity.
      (c) Standards for installation.
      (d) Operating temperature of burners.
      (e) Wavelength of infrared produced.
      (f) Advantages and disadvantages of gas infrared production versus electric or other means.

   C. Applications of Radiant Heat to Industrial Processes.
   1. Drying theory ("case hardening" limitation with too fast surface drying).
   2. Specific applications.
      (a) Drying at the wet end of paper machine.
      (b) Drying of coatings.
      (c) Pulp drying.
      (d) Preheating of sheets before pressing.

III. Summarize Paper and Review the Many Benefits Which Radiant Heating provides, such as:
   1. Rapid heating.
   2. Pattern and direction to heating.
   3. Precise temperature control.
   4. Instant response to demand.
   5. Compact and space saving equipment.
   6. Automated labor saving equipment.

R. C. Swaney stated that a half day session (9 a. m. to 12 noon) will be devoted to radiant heating. A request is to be made to the Engineering Division to assign time for two half-day sessions for the Drying Committee so that one session could be devoted to a symposium on "The Use of High Air Impingement for Drying."

The program for the symposium on "The Use of High Velocity Air Impingement for Drying" would consist of two parts. The first part would be the talk by Dr. Allander of the Swedish Flakt Co. on the theory of airdrying (possibly a paper by a second speaker). The second part of the program would be a panel discussion by users of high velocity air driers. The members of this panel will be picked after consultation with suppliers of the equipment. S. G. Holt is to write to the following companies disclosing the plans for this program—Rice Barton, Black Clawson, American SF Products, J. O. Ross, and Drew Engineering. He has written an invitation to Dr. Allander which has been accepted via Lars Blomgren.

Project 505, Drying Rates of High Pressure Driers. W. K. Metcalfe represented Mr. Janett at this committee meeting. The request has been made that Mr. Janett inform Mr. Holt with regard to the estimated manpower needed for the correlation work. A. J. Cirrito made a point that possibly the tabulated data would be more useful to the industry than correlated graphical data because of the large number of variables.

Project 755, Data Sheets Subcommittee. Chairman Holt stated that the Drying Committee has been lacking in data sheet output and also stated that Howard Stevens has resigned from the Drying Committee. (George Jackson has assumed the duties of subcommittee chairman.) Holt stated that he felt the committee should make an effort to produce four or five data sheets a year. It was agreed that readily available handbook data should not be made into data sheets.

A new project has been set up to develop good methods for moisture sampling of paper. The following members were accepted to be on the subcommittee: Mr. Pohlman, chairman, Mr. Krikorian, and Mr. Reitzel. The committee secretary was requested to send forms to establish new projects to Mr. Pohlman.

A committee meeting was planned for late May, 1960, at Wisconsin Rapids. May 26 was acceptable to members present as it would follow the TAPPI Coating Conference in Chicago. Mr. Holt stated that connections can be made via North Central Airlines. A block of rooms will be reserved at the Mead Hotel, Wisconsin Rapids, and the secretary will send the meeting reminder post cards well ahead of the May 26 meeting date.

The meeting was adjourned at 2:00 p.m.

K. K. Khandelwal, *Secretary*

Engineering Data Committee

H. G. Ingraham, Chas. T. Main, Inc., Boston, Mass., chairman of the Engineering Data Committee called the meeting to order at 3:00 p.m., Feb. 21, 1960. He introduced those present and indicated the committee each represented:

C. E. Bouis, Civil Engineering
C. L. Calehuff, Fluid Mechanics
A. J. Chase, Chemical Engineering
P. A. Goldsmith, Mechanical Engineering
H. B. Harris, Jr., Corrosion
H. G. Ingraham, *chairman*, Engineering Data
G. F. Jackson, Drying
J. Lewis, Chemical Engineering
W. A. Moggio, Sanitary Engineering
P. L. Nelson, Steam and Power
V. P. Owens, Engineering Division Staff
E. G. Parrish, Electrical Engineering
W. C. Pittam, Civil Engineering
A. W. Plummer, Chemical Engineering

Engineering Data Committee Meeting

E. W. Prince, Process Instrumentation
H. O. Teeple, *secretary*, Engineering Data

The first item on the agenda was a progress report on Project 787. This project was designed to assist the committee in ascertaining the extent of "readily available information of data sheet nature." A questionnaire was sent to all Engineering Division chairmen, vice-chairmen, and secretaries asking that each person list "standard references" which he found useful to him in his job. A further question was asked as to frequency of use, i.e. (1) "frequent," (2) "occasional," and (3) "last resort."

The response was good and the references were collated and the list distributed to those present. A discussion indicated the order of reference listing should be revised. Also more information on frequency of use is required in some cases. It was suggested this report might be published in *Tappi* as an aid to engineering people in the industry.

The next item on the agenda was a report from each committee on progress of the review of existing data sheets and the development of new ones.

Chemical Engineering—A. J. Chase reported that 36 data sheets had been reviewed and that 10 remained to review. He indicated the committee has four new data sheets under preparation, having to do with physical properties of chlorine dioxide and sodium chlorate.

He suggested that a substantial contribution could be made if each member of the Chemical Engineering Committee would submit *just one* data sheet per year.

Civil Engineering—W. C. Pittam reported his committee has three data sheets in the process of being reviewed.

Corrosion Committee—H. B. Harris, Jr., reported four data sheets have been reviewed, and that two are still in the committee.

Drying Committee—G. E. Jackson reported his committee has been reviewing CPPA data sheets with the thought in mind that this would be a good source of data sheets for TAPPI. He also reported his committee is looking critically at high velocity air drying as a source of useful data sheets.

Electrical Engineering—E. G. Parrish reported that of the reviewed data sheets, some should be eliminated and some should be revised. The revisions have been prepared and await publication.

Fluid Mechanics—G. L. Calehuff reported four possible data sheets have been assigned to the committee for study and two are being reviewed. He mentioned that data sheets are expected from each of the four subcommittees.

Mechanical Engineering—P. E. Goldsmith reported three data sheets are in process of review and three are in the development stage.

Process Instrumentation—E. W. Prince reported one in the development stage but that more information would be available after the forthcoming interim meeting of his committee.

Sanitary Engineering—W. A. Moggio reported his committee was investigating unusual methods of effluent measurement as a possible source of data sheets.

Steam and Power—P. L. Nelson reported substantial progress on the development of 21 data sheets on power piping.

Representatives from the Engineering Economics, Industrial Engineering and Materials Handling, and the Maintenance Engineering Committees were not present.

Chairman Ingraham urged the individual committees to complete the review of assigned data sheets and also that TAPPI publish promptly the revised as well as new data sheets as they are completed.

The subject of an interim meeting of the committee was discussed and it was indicated that committee meetings at the fall conference and again in February together with written interim reports would be adequate.

Chairman Ingraham asked for new business, and there being none, declared the meeting adjourned.

H. O. Teeple, *Secretary*

Electrical Engineering Steering Committee

Minutes of Electrical Engineering Steering Committee, meeting held Feb. 23, 1960, 2:00 p.m. at the Hotel Commodore, New York, N. Y.

Members present:

S. Andersen, *chairman*
E. G. Parrish, *vice-chairman*
H. A. Wright, *secretary*
M. M. Stokley
R. F. Sorenson
G. E. Shaad

Member absent: H. W. Thompson.

Guest present: M. A. Burnston—TAPPI representative.

The meeting was called to order by Chairman Andersen. The first item of business was the withdrawal of Mr. Shaad from the Electrical Engineering Committee. C. C. Collins of General Electric will be invited to become a member of our committee.

Copies of minutes and items of general interest to all will, in addition to being forwarded to members of the Electrical Engineering Committee, be forwarded to M. J. Osborne, N. Shoumatoff, V. P. Owens, H. O. Teeple, and G. E. Shaad.

The next meeting of the Electrical Engineering Committee will be held April 20, 1960, in the Continental Room of the Holiday Inn, Gainesville, Fla. The meeting will start at 8:30 a.m. The secretary will advise committee members of the above and, in addition, certain extracts from the AIEE mailing relative to their April 21–22 conference.

Mr. Stokley discussed the membership at length. It was agreed to make a concerted effort to obtain new members from the various paper mills. For the record, the following was agreed to:

1. The main committee membership will be limited to a 50–50 ratio between mill and manufacturing people.

2. There is no restriction on the number of manufacturers on the various subcommittees. It is the subcommittee chairman's responsibility to select those people either from mill or industry who will give him the most help on his projects.

3. Subcommittee members may or may not belong to the main committee. However, members of the subcommittee may attend all meetings of the main committee, but have no committee vote. Further, they need not be a member of TAPPI.

Chairman Andersen reviewed the evaluation report rendered for the Pittsburgh, Pa., meeting in October, 1959. The following items were of significant interest:

1. It is the speaker's responsibility to prepare good slides; cluttered and indistinct slides are not acceptable. Instruc-

Electrical Engineering Steering Committee

Engineering Economics Committee

tions for slides have been published by TAPPI which will be sent by the secretary to the various speakers.

2. A signal rather than a verbal request to the projector operator for changing slides should be used.

3. Several organizations have a speakers' breakfast at which time the last minute instructions are conveyed. It was mentioned that API followed this procedure, and that the Association picks up the tab for the speakers' breakfast. Chairman Andersen is going to investigate.

4. It is very bad manners for a speaker to run over his time; therefore, Mr. Wright is directed to make up a timer having a red, green, and amber light.

The program for the Fifteenth Engineering Conference was reviewed. Mr. Sorenson reported that his paper, "Ventilation of Electrical Equipment Rooms," had been presented in the Southeast area and that a goodly percentage of these people would be attending the Fifteenth Engineering Conference. Also, the AIEE Pulp and Paper Conference will present a paper on the same subject; therefore, it was agreed to withdraw this paper and substitute in its place four papers presented by title only. The following general schedule was agreed to:

9:20– 9:40	Project No. 790 "Purchased Power in Paper Mills."
9:40– 9:50	Discussion.
9:50–10:00	"Overload Protection of A. C. Machines"; title only.
10:00–10:10	Project No. 620. "Power Requirements of Feltless Pulp Machines"; title only.
10:10–10:30	Break.
10:30–10:40	Project No. 621. "Structural Board Machine Power Data"; title only.
10:40–10:50	"Selection of Refiner Motors"; title only.
10:50–11:40	Project 789. End Thrust Problems or Considerations of Flexible Coupled Motors; Panel Presentation.
11:40–12:00	Discussion.

The problem of a moderator for the panel is still with us. Mr. Sorenson will contact J. R. Fielding as a possible moderator if Mr. Minges has not made other arrangements.

The committee luncheon at the Fifteenth Engineering Conference will be held on Tuesday, at 12:30, in the English Room of the Hotel Robert Meyer. It will be followed by a business meeting.

The schedule for the Fifteenth Engineering Conference appears to eliminate the competition which has been present in the past for our technical sessions and, therefore, it is very satisfactory. One suggestion was to provide a portable mike for floor questions. This causes considerable confusion; therefore, it was agreed that the chairman will repeat the question from the platform and that he should be provided with a mike.

Mr. Parrish made a report on the data sheets with particular emphasis on those which had been submitted but not published. He will recheck his files and write Mr. Burnston of TAPPI headquarters who will provide a followup in order to have these sheets printed.

Chairman Andersen, through the various subcommittee chairmen, will cause to be made up a list of active and proposed projects for each subcommittee.

Chairman Andersen presented a proposed letter covering instructions to subcommittees. It was agreed that this was necessary and very timely. The committee again stressed the necessity for subcommittees to hold their meetings *prior* to the main committee meeting, and *not* after.

Generally speaking, our membership are not too pleased with the publicity received in *Tappi*. Few of our papers obtain technical status. There appears to be too much chemistry in this section. TAPPI headquarters has suggested that a number of our projects be made up into special reports; however, it is found that this media has a very limited distribution and unless corrected, we should resist this approach.

Meeting adjourned at 5:15 p.m.

H. A. WRIGHT, *Secretary*

Engineering Economics Committee

A meeting of the Engineering Economics committee was held at the Commodore Hotel in New York, N. Y., at 9 a.m., Wednesday, Feb. 24, 1960.

Attendance:

Members
George Sargent, Jr., *chairman*
Fred C. Holmes, *secretary*
Paul Toma, Time, Inc.
Ray Marsh, Walter Kidde, Engineers

Guests
William O. Smiley, Electric Eye Equipment
J. L. Rodriguez, Diamond National
George Gordon, Diamond National
Thomas O'Hare, M. W. Kellog Co.

First discussed activities of the past year and had comments on the two papers presented at the National Session in Pittsburgh last October. General feeling was that papers were very well received, even though both were technical and dealt with methods of economic justification of projects. At future meetings, arrangements are to have at least one paper giving an actual example of the justification of a project.

It is now suggested by TAPPI that this committee may wish to take an active part in the presentation of papers at the National TAPPI meetings in New York City each year. This will mean that all committee members will have to take a more active part in committee work.

Ray Marsh, chairman of the Subcommittee on "Bibliography of Articles on Economic Justification," asked that all members continue to send him copies of any article dealing with this subject.

Mr. Sargent, our chairman, again stressed the importance of securing more active members for the committee. This is a *must* if we are to continue to carry out the obligations for which this committee was established.

Discussed the two proposed papers for the October meeting this year. Drafts are being prepared for these papers.

1. "Economic Justification for Moisture Control," by William O. Smiley of the Electric Eye Equipment Co., Danville, Ill.
2. "Concepts of Budget Control," by the M. W. Kellog Co. (Actual speaker has not yet been selected.)

Beloit Iron Works has agreed to present a paper on the economics of the Inverform.

Speakers will also be contacted relative to papers on "Batch Pulping versus Continuous Pulping" as well as "Screw Press Washing versus Drum-Type Washing."

Meeting adjourned at 11:30 a.m.

FRED C. HOLMES, *Secretary*

Fluid Mechanics Subcommittee on Free Surface Flows

The meeting opened with subcommittee appointments of A. C. Spengos to vice-chairman and C. A. Lamb to secretary.

Subject: Instability of Stock on the Fourdrinier Wire, University of Michigan, Ann Arbor, Feb. 4, 1960.
Present:
C. A. Lee—Fluid mechanics *chairman*
P. E. Wrist—Subcommittee chairman
A. C. Spengos
C. A. Lamb
W. Debler, D. W. P. Graebel, A. Engerer—University of Michigan
S. G. Mason—Subcommittee on dilute fiber suspensions, *chairman*

P. E. Wrist presented the Agenda for the day which was well followed throughout the meeting. The first part of the meeting was devoted to a review of the scope and intent of the work at Michigan. Dr. Debler then presented the results of the past year's work. This was followed by a summary of the benefits of the project and a discussion of future work which would be the basis for an application to the Research Appopriations Committee for a new TAPPI project grant.

Scope and Intent of Project. Mr. Wrist read the original project writeup, reviewed the reasons for some of the changes which were made at the subcommittee meeting in January, 1959, and subsequently reported in the minutes of that meeting published in *Tappi*. The primary deviation was to postpone indefinitely the work with actual papermaking slurries or papermaking machines unless it were necessary to establish a basic concept. Such an extension would have greatly diluted the excellent theoretical and experimental work the University was accomplishing. C. A. Lee elaborated in support of the above, that TAPPI projects should consist of basic work. The paper companies can then apply the results to their own specific applications.

Dr. S. G. Mason commented on some of the work that the University of Michigan had done on their own initiative and time. He was very interested in their use of fibers in a vortex apparatus, and felt that their suggestion that this might have application to viscosity determinations was worth following up.

Presentation of 1959 Work. Dr. Debler started his summary by describing the modifications on the experimental equipment. The major ones involved and improved flow-approach section, headbox and slice section. The changes had resulted in better reliability. Measurements with the improved equipment were somewhat different in detail but generally confirmed the earlier test results.

Dr. Debler explained that Dr. Yih had done a considerable amount of related work outside of TAPPI support. He had essentially completed an analysis of the instability of a film of liquid on the outside surface of a rotating roll. The theory included both surface tension and viscosity effects. This work, with TAPPI permission, had been submitted for publication by the Proceedings of the Royal Society by Sir G. L. Taylor.

Reprints of "Free Surface Instability" by Yih and Spengos were distributed to all members. More recent data obtained with the improved apparatus were also presented by Dr. Debler. Mr. Spengos thought the new experimental determinations of the rebound phase of spouting differed appreciably from his earlier results and indicated that the earlier region of downward acceleration over the table roll might be confounding the picture. These results would necessitate a revision of some of the earlier thinking. The group agreed that it might be desirable to study an isolated phenomena of upward acceleration in the next program.

Dr. Debler indicated their desire to get a better measurement of the height of disturbances. He showed some photos directed at this end and stated that they would give a better appraisal of this approach in his final report on April 1. They would also have results obtained with a larger diameter roll for reporting at that time.

Future Work. Mr. Wrist then summarized the various aspects of flow instability that might be a basis for future work:

A. Continuation of work on spouting on the fourdrinier.
B. A study of streak formation in the headbox slice.
C. Instabilities of a non-Newtonian liquid on rotating rolls; "turkey tracks" from roll coating being an example.

Dr. Mason presented a considerable quantity of data obtained from various paper considerable discussion by Messrs. Wrist and Lee indicating that many of these cases may have been due to mechanical reasons such as holey roll hole spacing. It was acknowledged that some natural vortex formation in the slice region could account for some of these cases and that an understanding of this phenomena was of considerable importance in slice design.

It was agreed that items (a) and (b) would be most appropriate basis for new work at this time. Mr. Wrist will draft the proposal for next year's work. This will be submitted for Dr. Yih's approval before final presentation to the parent committee in New York on Feb. 24, 1960.

The meeting closed with a discussion of the side benefits of the project. Foremost was that the project had done much to make the university students and staff aware of challenging technical problems in the paper industry. Dr. Debler, himself, had attended the APPA meeting that was concerned with this subject. The spouting apparatus is one of their more spectacular demonstrations and has been of considerable interest to students, staff and visitors. Dr. Spengos said he would probably not have gone to work in the paper industry if it were not for the interest aroused while working on this project.

C. A. LAMB, *Secretary*

Systems Engineering and Operations Research Subcommittee

E. F. Thode, The Institute of Paper Chemistry, Appleton, Wis., chairman of the Systems Engineering and Operations Research Subcommittee of the Chemical Engineering Committee, opened the meeting at 2:10 p.m., Feb. 23, 1960.

Chairman Thode announced this was a joint meeting with the APPA Ad Hoc Committee on Operations Research and extended a cordial welcome to those present who were:

C. W. Carroll, Scott Paper Co., TAPPI
R. Cummings, Union Bag-Camp Paper Corp., TAPPI
M. J. Fabrikant, Hudson Pulp and Paper Co., APPA

J. Gessford, International Paper Co., APPA
A. Gniazdowski, Great Northern Paper, APPA
T. A. Hewson, St. Regis Paper Co., TAPPI
A. F. Johnson, Buckeye Cellulose Corp., TAPPI
J. Lewis, Pulp and Paper Research Center, Inc., TAPPI
J. B. Lockhart, Jr., Riegel Paper Corp., APPA
C. E. McCarty, Scott Paper Co., TAPPI
J. T. Penninger, International Paper Co., APPA
A. W. Plummer, Hudson Pulp and Paper Co., TAPPI
F. E. Pollock, Buckeye Cellulose Corp., TAPPI
H. O. Teeple, TAPPI, TAPPI
E. F. Thode, The Institute of Paper Chemistry, TAPPI
R. W. Van Duyne, West Virginia Pulp & Paper Co., APPA

Chairman Thode opened the discussion based upon a previously prepared agenda by telling of the plans by the TAPPI O. R. subcommittee for the Fifteenth Engineering Conference to be held Oct. 24–27, 1960, at the Robert Meyer Hotel in Jacksonville, Fla. He stated the session to be sponsored by this subcommittee would consist of four educational type papers dealing with "operations research tools." The papers would be on (a) linear programming, (b) response surface techniques, (c) inventory and other probability models, and (d) simulation. Authors have been procured for papers (b) and (d). An invitation was extended to those present to author, or arrange for authors, for the remaining two papers. (*Note:* Subsequent to the meeting an offer was received from one of the attendees.)

Extent of Paper Industry Involvement in Operations Research—Discussion of TAPPI Questionnaire. Returns from the questionnaire circulated in January were summarized on February 15 in a memorandum to all who had originally been sent the questionnaire. Among the dozen companies reporting, operations research activity ranged from some rather minor problem solving to full fledged departments employing a half dozen or more professional workers. Some of the companies which did not have formally designated operations research departments were carrying on as extensive a program in this area as those that did. It was noted that very few of the individuals doing O. R. work in our industry had had formal training in the sense of taking courses in collegiate institutions which had been specifically designated as operations research. On the other hand virtually all participants had had quite a significant amount of training in the mathematics and statistics required to gain a knowledge of the so called "tools" of operations research.

Working Definitions of O. R. There seems little difficulty over a working definition of O. R. as far as the paper industry is concerned. Two thirds of the replies to the questionnaire endorsed one of the two following definitions: (1) application of the tools of O. R. to any problems within the company or (2) mathematical and scientific analysis of company wide economic problems. These two definitions really are very much of similar import.

The Three Major Problems in Any O. R. Question, (a) the Technical Problems, (b) the Semantics Problem, (c) the Effectiveness Problem. It was pointed out that the large-scale systems most often studied in operations research invariably should be considered communications systems insofar as a major portion of the problem is concerned. There are three levels of difficulty in any communications system. First, there is the technical problem, which, while often extremely complex, is really the simplest of all. Next in difficulty is the semantic problem—that of being certain that meanings are properly conveyed. Finally, at the highest and most difficult level, is the effectiveness problem, where it is necessary to see that the transmitted meanings are translated into effective and desirable action.

During the discussion on these topics, it became apparent that some of those present did not realize that a serious semantic problem may exist among people with similar levels of intelligence and education. For example, the very simple term, "raw material cost," may mean one thing to an accountant in the controller's office and quite another thing to a plant technical service man. To move into the area of effectiveness, an example was given where an important department had an extremely serious inventory problem in the eyes of management. In the eyes of the operating personnel, however, they had no problem at all. The discussion served to bring out the very important point that the semantic problem is one with which all specialists connected with O. R. must deal. This includes the engineering and scientific individuals as well as the accounting, marketing, and general business specialists. It is furthermore apparent that the effectiveness problem is largely a problem of general management.

The Mathematical and Scientific Tools of O. R.—The Technical Problem. The discussion of this item revealed that objectivity is important. Tools would consist of anything which may be involved in the solution of the problem, i.e., mathematics, machines, the ingenuity and experience of the O. R. people.

Need for Close Liaison Among Various Specialists to Deal with the Semantic Problem. This was agreed to be important to both TAPPI and APPA.

Need for Close Liaison of Specialists with Management to Deal with the Effectiveness Problem. The discussion of this item indicated it may be primarily an APPA function.

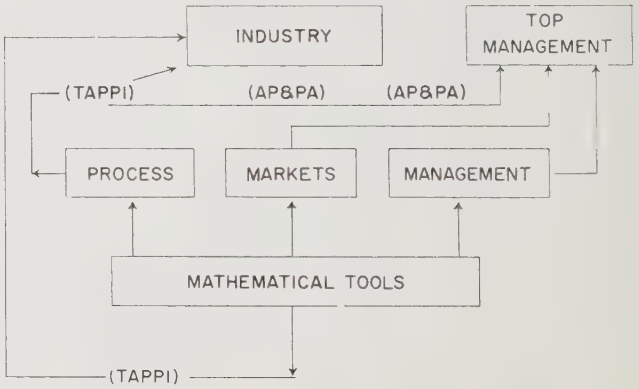
Need for Development of Commonly Required Techniques Without Reference to Possibly Confidential Applications. The discussion of this item indicated it was probably of major interest to TAPPI.

Need for Discussion of Applications without Reference to Confidential Data. It was suggested that APPA would be of significant help in securing management assistance when needed.

In What Way May TAPPI Contribute to the Needs of the (Pulp and) Paper Industry in the O. R. Area?

In What Way May TAPPI Complement the Activities of Other Groups, Such as APPA, in this Area?

In a discussion of these two items, it was suggested the following chart may serve to delineate several viewpoints.



Further, the discussion revealed, in O. R. application, committee activity is needed both in TAPPI and in APPA. Perhaps TAPPI emphasis would be on the technical problem whereas APPA emphasis would be on management relations. Common areas, which certainly exist, would involve strong liaison activity on the part of each association committee.

In summary, there appears to be a more serious need for liaison among the mathematical, engineering, and economic specialists rather than between technical and management.

In the ensuing months, efforts will be made to effect a strong liaison committee between the two associations and perhaps plan to present a jointly sponsored O. R. session next February during Paper Week.

H. O. Teeple, *Secretary, pro tem.*

Paper and Board Manufacture Division

Fourdrinier Committee

A meeting of the Fourdrinier Committee was held in the Commodore Hotel on Monday, Feb. 22, 1960. Chairman Kennedy opened the meeting with the following in attendance:

C. L. Brown
M. Burnston
J. H. Cowan
R. Connick
J. Hannegan
P. H. Hershey
C. L. Hess
R. W. Hisey
R. T. Hudson
W. H. Kennedy
R. N. King
J. W. Hierlihy
R. C. Masterman
H. H. Morton
H. H. Mullins
R. W. Peters
R. C. Porter
J. Stevensen

Project No. 635—The Problems of High-Speed Machine Operations. This project has been referred back to Mr. Kennedy, due to Mr. Levensailor leaving for overseas.

Fourdrinier Committee of the Paper and Board Manufacture Division

Project 802—Wet End Process Control. Mr. Hershey reported on the subcommittee meeting on this project on Rochester, and presented a draft questionnaire, which was accepted as revised.

Project No. 734—Dandy Roll Practices. Mr. Hannegan reported that the questionnaire was sent out and 75 replies have been received. A final report should be ready this summer.

Project No. 737—Rope Carrier Practices. Tige Mullins will close this project out successfully by presenting a paper during the convention.

Mr. King reported his extensive work on "Vacuum box suction variation across the web." This has led to the problem of determining the system requirements for vacuum as affected by grade, speed, etc.

Project No. 792—Suction Box Covers. Mr. Morton reported the progress made. As of now, two mills, three rubber companies, and one university are interested and working. The object is to investigate new materials for suction box covers. Mr. Morton will process the project to secure a research grant by TAPPI.

Mr. Burnston requested that project numbers be used on all correspondence.

The spring meeting will be held in Fort William, Ont., on May 5 and 6 in combination with a visit to Great Lakes Paper Co.

ROBERT W. HISEY, *Secretary*

Pulp Manufacture Division

Alkaline Pulping Committee

Chairman J. Mck. Limerick called the Alkaline Pulping Committee meeting to order at 2:00 p.m. at the Commodore Hotel, New York City, Feb. 21, 1960, and thanked those in attendance for making the meeting. The minutes for the previous meeting were reviewed on motion of David Wetherhorn. Seconded by Paul West, the minutes were accepted.

New members for the committee were considered. Edward F. Thode and T. T. Collins were appointed members of the committee.

The resignation of Fred Bishop was discussed and regretfully accepted.

H. O. Teeple of TAPPI reported on the successful fall meeting in Jacksonville and indicated the meeting wound up with a surplus of income over expenses around $1959.

R. R. Fuller reported as program chairman of the 1960 Annual Meeting Program covering plans for the Monday morning meeting of the group. In spite of the unusual meeting time, our Annual Conference was very well attended and went off in fine fashion.

Chairman Limerick called on H. Y. Charbonnier, chairman of the Nominations Committee, to nominate officers for the coming year. Mr. Charbonnier stated after careful consideration the committee wished to submit the names of David Wetherhorn for chairman and Paul West for vice-chairman. Without discussion, it was voted to unanimously accept the suggestion of the Nominating Committee and the secretary cast a unanimous vote for Chairman Wetherhorn and Vice-Chairman West.

Mr. Limerick indicated his pleasure of having been chairman for the past two years. He thanked the members of the committee for the support thay had given and generally expressed his appreciation for the progress made under his chairmanship. While it has not been practice in the Alkaline Committee to do so, Mr. Limerick thought that he would like to turn the meeting over to Mr. Wetherhorn as incoming chairman, asking Mr. Wetherhorn to accept the chair. The balance of the meeting was then conducted by David Wetherhorn.

Mr. Wetherhorn discussed general plans for the coming fall meeting and arrangements with the West Coast people.

H. O. Teeple reported on the meeting place and the general progress in getting the meeting located and handled.

Paul West, program chairman for the fall meeting, discussed the possibilities of the technical program and mentioned

Alkaline Pulping Committee

that seven or eight papers were already in line. A discussion of papers and locations ensued and it seems the meeting is well under way.

The newly formed Sulfite Pulping Committee will take a half day of the program.

Mr. Wicket, representing the West Coast, was not present and the local situation could not be ascertained. Possible papers developed by the annual February meeting were turned over to Mr. West.

The Fifteenth Alkaline Pulping Conference was discussed but no formal report was made. The meeting will be held in the Rice Hotel on Nov. 1–3, 1961, in Houston, Tex.

The Sixteenth meeting possibilities were discussed. Mr. Teeple and Mr. Wetherhorn agreed to see about hotels in the Savannah area for the 1962 conference.

D. C. Gillespie reported for the Monograph Committee and discussed the difficulties of finding someone to be editor-in-chief of this monograph. This matter was discussed at some length and it was decided to try to persuade R. P. Whitney of The Institute of Paper Chemistry to accept the job before the February meeting was over. Chairman Wetherhorn and the committee agreed to contact Mr. Whitney during the February meeting. Chairman Wetherhorn indicated later in the week that Mr. Whitney had formerly accepted the editorship of the monograph.

Mr. Wetherhorn reported for the Testing Committee and submitted copies of test proposals activity test for black liquor, and analysis of sulfate black liquor.

Mr. Wetherhorn pointed out an error in the test method—page 2 of the analysis of black liquor, ammonium hydroxide should be used instead of sodium hydroxide.

R. B. Kessler of The Institute of Paper Chemistry was appointed the new chairman of the Subcommittee on Testing.

In the absence of P. B. Borlew, a report was not made for the Subcommittee on the Chemistry of the Sulfate Cook and Digester Corrosion.

The question of new committee projects was raised and considerable time was spent in discussing possible projects as well as projects we are now carrying along. It was suggested that all future work be classified as projects in order to keep the records straight. F. Thode of The Institute of Paper Chemistry was appointed chairman of a committee to gather information on nonconventional methods of pulping. Mr. Thode was to appoint his own committee members.

On a motion by Mr. Limerick, seconded by Mr. West, the meeting was adjourned.

Those in attendance were:

T. C. Bannister
R. E. Bowen
H. Y. Charbonnier
R. R. Fuller
Dan C. Gillespie
P. L. Gilmont
E. A. Harper
W. E. Haviland
J. Limerick
J. N. McGovern
J. Parrott
A. W. Pesch
Wm. B. Stengle
H. O. Teeple
E. F. Thode
P. H. West
D. Wetherhorn
V. Woodside

Deinking Committee—Annual Report

During the past year the Deinking Committee has functioned within the organizational procedures as outlined by TAPPI and under committee rules. The committee rule provides for the development of continuous committee leadership by the annual progression of officers through the various posts to chairmanship. For 1959 the officers were sa follows:

Chairman.....W. Doyle Boggess, The Beveridge Paper Co.
Vice-Chairman.....E. F. Andrews, International Paper Co.
Secretary.....A. J. Felton, The Black-Clawson Co.
Program Chairman....H. E. Corwin, Diamond Gardner Corp.

The main activities of the committee during this period have been as follows:

Meetings. Committee meetings were held on Feb. 23, 1959, TAPPI Convention, New York City, with 20 people in attendance; and Oct. 7, 1959, Deinking Conference, Holyoke, Mass., with 19 people in attendance.

Fourth Deinking Conference, Holyoke, Mass., Roger Smith Hotel, Oct. 7–9, 1959, approximately 125 in attendance. This was a very successful conference from the standpoint of technical program as well as mill visitation. John W. Wendell, Jr., was general conference chairman and H. E. Corwin, technical program chairman. Plans are under way for the 1960 Deinking Conference under the general chairmanship of James T. Allen. This conference will be held at the Conway Hotel, Appleton, Wis., on Oct. 5–7, 1960.

Committee Project No. 732. Standard Method for Evaluating Waste Paper for Deinking Suitability. This was a questionnaire sent to 46 mills reported doing deinking. Replies indicated no standard method of deinking. Most mills have laboratory deinking methods which they feel correlate satisfactorily with mill practice. However, a subcommittee—consisting of Chairman Merle Wilkins, Kalamazoo Paper Co., Al Altieri, Tileston & Hollingsworth, and John Wendell, Tileston & Hollingsworth— was appointed to study the replies from this questionnaire in order to develop from them, if possible, a laboratory deinking method or methods which could be submitted for inclusion in TAPPI Routine Control Methods.

Committee Project No. 733. Deinking Practices Questionnaire. This committee prepared a two-part questionnaire regarding deinking practices. Part I has been circulated and results are being compiled.

Chairman, J. A. Dean, Hamilton Paper Co.
M. R. Wilkins, Kalamazoo Paper Co.

Program Advisory Committee. During 1959 this committee has been expanded to consist of a nucleus of six members on a rotating basis with one new member appointed each year by the Deinking Committee chairman. This committee has the responsibility for assisting the technical program chairman for future conferences.

Chairman, J. L. Clouse, Oxford Miami Paper Co. (1960)*
A. M. Altieri, Tileston & Hollingsworth (1961)
J. Forsythe, International Paper Co. (1962)
A. J. Felton, The Black-Clawson Co. (1963)
O. P. Fussell, Federal Paper Board (1964)
Merle Wilkins, Kalamazoo Paper Co. (1965)

Research Projects Committee. This committee is still actively working on the "Sticky Materials" project appropriation request and currently is studying proposals to select one which will be submitted to the Research Appropriation Committee.

Chairman, A. M. Altieri, Tileston & Hollingsworth
E. F. Andrews, International Paper Co.
J. J. Forsythe, International Paper Co.
W. D. Boggess, The Beveridge Paper Co.
J. L. Clouse, Oxford-Miami Paper Co.

Conferences—Annual or Biennial. The Deinking Committee voted unanimously to continue the conferences on an annual basis. The reorganization of the Program Committee so as to bring some real assistance to the preparation of the technical program was a factor in reaching this decision.

Committee Membership. The membership of the committee was brought up to date as of Sept. 23, 1959, and a committee membership application form was approved at our last Deinking Committee meeting..

W. Doyle Boggess, *Chairman*

Deinking Committee

The Deinking Committee meeting opened at 2:00 p.m. by Doyle Boggess, chairman. The following people were present:

* Year in parentheses indicates date term expires.

Deinking Committee

D. Boggess, Beveridge Paper Co., Indianapolis, Ind.
E. F. Andrews, International Paper Co. Niagara Falls, N. Y.
A. Felton, Black-Clawson, Middletown, Ohio
M. Michelsen, R. R. Donnelley & Sons, Chicago, Ill.
J. Forsythe, International Paper Co., Niagara Falls, N. Y.
A. M. Altieri, Tileston & Hollingsworth, Boston, Mass.
A. M. Brooks, Columbia-Southern Chemical Co., Pittsburgh Pa.
D. J. Clark, Simpson Paper Co., Everett, Wash.
T. T. Allan, Virginia Smelting Co., Boston, Mass.
J. R. Radley, Falulah Paper Co., Fitchburg, Mass.
C. O. Anastasio, Lowe Paper Co., Ridgefield, N. J.
D. B. Geffhern, Sealright-Oswego Falls Corp., Fulton, N. Y.
W. H. Somus, Dow Chemical Co., Midland, Mich.
J. L. Clouse, Oxford Paper Co., West Carrollton, Ohio
G. A. Graham, Waste Paper Utilization Council, New York City
R. W. Kumler, Waste Paper Utilization Council, New York City
P. J. Schmitt, P. H. Glatfelter Co., Spring Grove, Pa.
R. A. Barton, Virginia Smelting Co., West Norfolk, Va.
M. R. Wilkins, Kalamazoo Paper Co., Kalamazoo, Mich.
M. D. Reuben, Erving Paper Mills, Erving, Mass.
J. W. Wendell, Jr., Tileston & Hillingsworth Co., Hyde Park, Mass.
L. R. Adkins, Waterfalls Tissue Corp., Mechanic Falls, Me.
H. E. Corwin, Diamond National Corp., Palmer, Mass.
F. Caskey, Morden Machines Co., Portland, Ore.
R. W. Pattison, Berkshire Color & Chem. Co., Springfield, Mass.
G. H. Baldauf, Allied Paper Corp., Kalamazoo, Mich.

The minutes of the October meeting at the Fourth Deinking Conference were read and approved.

Project 732—M. Wilkins, *chairman,* reported no contact with members since questionnaires were inadvertently held at TAPPI headquarters. Herb Teeple is to be contacted and requested to forward the replies to Merle Wilkins.

Project 733—Report for Art Dean by Merle Wilkins. The answers to Questionnaire 733—Part 1 have been received. The report is to be compiled as in previous reports by TAPPI with all members reporting on each question, but coded so that identity is concealed.

Part I: 40–50 mailings, 18 returns. Balance to be contacted by mail with request for reply. Report to be compiled by October 1960.

Part II: This report to be completed by December, 1960.

Sticky Material—Mr. Altieri, chairman (third writing), believes that an 8 to 10 member committee should be formed to help work with cylinder machine group to obtain collaboration.

Mr. Higgins requested and received 15 copies of the revised request for the cylinder board group. Decision is to be made "for or against" by the February, 1960 meeting. Foster Doane has been sent a copy of the project but he suggests additional work and contacts with Project Appropriation Committee to enlighten them.

The suggestion was advanced that individual mills finance project along with the Institute of Paper Chemistry.

Membership Application—The form drawn up by Chairman Boggess was approved and accepted. Retention of committee membership. *Motion:* If a committee member becomes inactive (fails to attend a meeting or is inactive for any reason) for a period of 2 years he will be dropped from the committee. Seconded and approved.

Program Advisory Committeee—The present committee was explained by John Clouse. It was suggested this committee be reconstituted as Steering Committee. Its activities would deal with (1) planning the technical programs, (2) choosing the site for conference, and (3) formalization of committee policy. *Motion:* Committee will be renamed Deinking Steering Committee and will at each fall meeting name for 2 years ahead when, where, theme, program chairman and general chairman. Seconded and approved.

The 1960 Conference will be at the Conway Hotel, Appleton, Wis., Thursday, October 6 and Friday, October 7. The following conference officers were named:

Henry Stevens, *treasurer*
Milton La Fever, *publicity and secretary*
James D. Allen, *general chairman*
Robert Kinne, *program chairman*

For plant tours, Bergstrom Paper Co. and the Institute of Paper Chemistry were selected.

New committee officers installed. Effective as of the February meeting are:

E. F. Andrews, *chairman*
International Paper Co.
Niagara Falls, N. Y.
A. J. Felton, *vice-chairman*
Black-Clawson Co.
Middletown, Ohio
H. E. Corwin, *secretary*
Diamond National Corp.
Palmer, Mass.

The meeting adjourned at 4:30 p.m. with expression of thanks and appreciation to the retiring chairman, Doyle Boggess, for a job well done.

Dissolving Pulp Committee

Minutes of the meeting at Hotel Commodore, New York City, on Monday, Feb. 22, 1960, at 2:00 p.m.

The following members and guests were present:

Merle Heath, Buckeye Cellulose Corp., Memphis, Tenn.
Mark Plunguian, Hercules Powder Co., Wilmington, Del.
Forrest Simmonds, Forest Products Laboratory, Madison, Wis.
Milton Schur, Olin-Mathieson Chemical Corp., Pisgah Forest, N. C.
Edward Howard, Industrial Cellulose Research Corp., Hawkesbury, Ont.
G. Hunger, Institute of Cellulose Chemistry, Darmstad, Germany
R. W. Swinehart, The Dow Chemical Co., Midland, Mich.
J. N. McGovern, Parsons and Whittemore, New York, N. Y.
T. L. Kirtley, Hercules Powder Co., Hopewell, Va.
D. F. Durso, Buckeye Cellulose Corp., Memphis, Tenn.

Election of Officers. The present officers were re-elected for a second term in 1960, i.e.:

Merle A. Heath, *chairman,* Buckeye Cellulose Corp., Memphis, Tenn.
Edward J. Howard, *vice-chairman,* I.C.R., Ltd., Hawkesbury, Ont., Can.
Mark Plunguian, *secretary,* Hercules Powder Co., Wilmington, Del.

Program for Future meetings. For next year's Annual TAPPI meeting it was decided to sponsor a full-day symposium on "Cellulose in Plastics, Sheetings and Film."

It was decided to try to sponsor a meeting, at a time and place different from the Annual TAPPI meeting, on the subject "How can we promote the future of dissolving cellulose" to be participated in primarily by producers and consumers

Dissolving Pulp Committee

of dissolving pulp. The chairman will appoint a subcommittee to contact TAPPI management with regard to organizing such a meeting.

Plans for a TAPPI Research Project. It was decided to try to get TAPPI to sponsor a research project on "The Mechanics of Swelling Cellulose in Various Media, Particularly the Formation of Alkali Cellulose, as a Preliminary to Further Reaction with Modifying Agents."

Various members of the Dissolving Pulp Committee have undertaken to contact five potential investigators in different laboratories, in order to narrow down the above broad subject to a specific phase. These proposals will then be circulated to the Committee members before submitting to TAPPI prior to the October 1 deadline for such requests.

Transcript of Discussions of 1959 Symposia. The Stenotypic transcript of the two symposia at last year's Annual TAPPI meeting (on the differences between cotton linters and wood pulp cellulose and on measuring the color of cellulose) have now been circulated to and edited by all those who participated in the discussions. The chairman will approach TAPPI about publishing this record as a whole.

The meeting adjourned at 4:45 p.m.

MARK PLUNGUIAN, *Secretary*

Sulfite Pulping Committee

The meeting was called to order at 2:10 p.m., Feb. 22, 1960, by Paul Frost, chairman, Acid Pulping Committee and Paul Trout, chairman, Semichemical Pulping Committee. The following were present:

P. J. Frost, Crown Zellerbach Corp., Camas
P. E. Trout, Waldorf Paper Products Co.
C. B. Christiansen, Diamond Alkali Co.
E. F. Thode, The Institute of Paper Chemistry
E. L. Smith, Combustion Engineering, Inc.
R. L. McCray, Crown Zellerbach Corp., Bogalusa
P. L. Gilmont, Olin Mathieson Chemical Corp.
G. C. Kimble, Union Bag-Camp Paper Corp.
F. J. McCourt, International Paper Co., York Haven
J. D. Miller, International Paper Co., York Haven
R. H. Taylor, Finch, Pruyn Co., Inc.
N. Sanger, U. S. Forest Products Laboratory
L. N. Johanson, University of Washington
J. L. McCarthy, University of Washington
J. S. Hart, St. Lawrence Corp.
C. K. Textor, Bauer Brothers, Inc.
R. T. Boyer, Consultant
K. J. Brown, E. D. Jones
E. D. Cann, Chas. T. Main, Inc.

The first item of business was consideration of the uniting of the Acid Pulping and Semichemical Pulping Committees to form a Sulfite Pulping Committee. P. J. Frost summarized the advantages of such action as being:

1. Elimination of overlapping areas of committee action and jurisdiction such as chemicals recovery and high yield sulfite pulping.
2. Formation of a single, stronger committee that would strengthen the TAPPI organization as well as facilitating better service to the entire sulfite pulping industry.

The scope of the Sulfite Pulping Committee activity would extend to all processes wherein the sulfite ion is the main pulping ion, including chemical recovery and pulp screening and washing.

After discussion, union of the two committees into a Sulfite Pulping Committee was moved by F. J. McCourt and seconded by E. L. Smith. The motion was passed unanimously.

P. J. Frost nominated the following candidates to serve as officers of the Sulfite Pulping Committee for the ensuing year:

Paul Trout, *chairman*
P. J. Frost, *vice-chairman*
S. R. Parsons, *secretary*

J. S. Hart moved closure of nominations and election of the slate as nominated, E. L. Smith seconding. Motion passed.

The next item was consideration of an invitation from the Alkaline Pulping Committee to the Sulfite Pulping Committee to sponsor a half-day session at the Fourteenth Alkaline Pulping Conference to be held August 22–24 in Portland, Ore. Acceptance of the invitation was moved by P. J. Frost, seconded by J. L. McCarthy, and passed by unanimous vote. P. J. Frost was appointed to handle arrangements for the Sulfite Pulping Committee session. All present were requested to assist in securing technical papers for presentation at this meeting.

Publication of the "Sulfite Pulping Recovery Systems" papers being presented at the current TAPPI meeting as a TAPPI monograph was discussed. E. F. Thode pointed out that three systems were not represented. These are The Institute of Paper Chemistry process, the Zimmerman process, and the Rayonier process. Consideration was also given the possiblity of combining sulfite recovery with the monograph being prepared on alkaline recovery but it was felt that this might greatly delay publishing of the sulfite recovery information. J. L. McCarthy and P. J. Frost were appointed to assemble the "Sulfite Pulping Recovery Systems" papers, together with papers on The Institute of Paper Chemistry and Rayonier processes if possible, for as rapid publication as possible.

F. J. McCourt submitted a questionnaire sent to acid sulfite pulping mills to determine the areas in which committee activity or investigation is desired. A copy of this questionnaire is to be sent to all members attending this meeting for their consideration. If it appears desirable, a similar questionnaire will be circulated to neutral sulfite semichemical pulping mills.

The first item of new business was passage of a motion to sponsor a sulfite pulping session at the 1961 Annual TAPPI Meeting. Again, all committee members were asked to assist in obtaining technical papers for presentation.

C. B. Christiansen was appointed to function as liaison between the Sulfite Pulping Committee and the TAPPI Corrosion Committee.

J. H. McGovern, Pulp Manufacture Division chairman, reported that research funds were available for sponsorship of research work by TAPPI. The Sulfite Pulping Committee stated that it was not currently considering any projects that might require TAPPI sponsorship.

It was suggested that managements of companies concerned in sulfite and neutral sulfite pulping be advised of the formation of the Sulfite Pulping Committee and the representation of their company (if any) on the committee.

Meeting adjourned 3:50 p.m.

PAUL TROUT, *Secretary, pro tem.*

Research and Development Division

Forest Biology Committee

The third regular meeting of the TAPPI Forest Biology Committee was called to order at 9:10 a.m., Feb. 23, 1960, by Chairman Donald D. Stevenson, in Room E, Hotel Commodore, New York, N. Y. Thirteen members of the committee or their representatives attended this meeting, with Harry Lewis and A. J. Winchester interested guests for part of the session. In attendance were:

Lowell Besley, Pulp & Paper Institute of Canada, Montreal, Que.
Charles Carpenter, Charles Carpenter, Little Rock, Ark.
Keith W. Dorman, Southeastern Forest Experiment Station, U.S.F.S., Asheville, N. C.
Charles H. Driver, International Paper Co., Bainbridge, Ga.
John W. Johnson (*secretary*), Union Bag-Camp Paper Corp., Savannah, Ga.
Bernhard K. Mayer, Oxford Paper Co., Rumford, Me.
Fred E. Pollock, Buckeye Cellulose Corp., Memphis, Tenn.
Earl Stephens, Champion Paper & Fibre Co., Hamilton, Ohio
Donald D. Stevenson (*chairman*), Buckeye Cellulose Corp., Foley, Fla.
Rolland F. Sultze (for R. J. Seidl), Simpson Timber Co., Seattle, Wash.
Edward F. Thode, The Institute of Paper Chemistry, Appleton, Wis.
Philip C. Wakeley, Southern Forest Experiment Station, U.S.F.S., New Orleans, La.
F. F. Wangaard, Yale School of Forestry, New Haven, Conn.
Visitors:
Harry Lewis, Appleton, Wis.
A. J. Winchester, TAPPI Staff, New York, N. Y.

Chairman Stevenson passed out copies of a short agenda, the subject matter of which was followed throughout the meeting. These minutes present the discussions of the various items on the agenda.

Membership changes. Chairman Stevenson introduced Messrs. Lowell Besley, Earl Stephens, F. F. Wangaard, and E. F. Thode, new members of the Forest Biology Committee, and Charles Carpenter, member since 1958 attending his first committee meeting. Chairman Stevenson announced that Philip N. Joranson of The Institute of Paper Chemistry had accepted the chairmanship of Subcommittee No. 2 on Tests and Quality Objectives.

Report on the Society of American Foresters' Forest Tree Improvement Committee Meetings at Placerville and San Francisco, Calif. Philip Wakeley presented a full report of the S.A.F.'s Tree Improvement Committee meeting that was held in California in November, 1959. The meeting began with a tour of the Institute of Forest Genetics at Placerville, Calif.; this was followed by a joint meeting with the Western Forest Genetics Association. All told, 10 papers were presented at the joint meeting. While all of these were of high quality, according to Wakeley, none dealt with wood quality or heritability of wood quality.

Wakeley reported that 25 seed orchards have been established so far in the Pacific Northwest and California, totaling approximately 129 acres. On the subject of seed orchards, Wakeley reported considerable heat generated in the Western Forest Genetics Association meeting over action taken by the International Crop Improvement Association at its October, 1959, meeting in Tulsa, Okla. The trouble stemmed from almost a complete misunderstanding on the part of the Western Forest Genetics Association of certain actions of the International Crop Improvement Association. Wakeley, Dorman, and Besley, all suggested that very definite attention be paid to correspondence, communiques, and reports with respect to labeling and dating. Proper attention to these details would have prevented the misunderstanding with the Western Forest Genetics Association. Wakeley further advised that the TAPPI Forest Biology Committee move circumspectly if and when it feels impelled to introduce wood quality specifications into existing or proposed forest tree certification standards. Evidently, the matter of seed certification standards is something of a touchy subject in certain regions.

In connection with Wakeley's report of a similar discussion at the Placerville meeting, Besley and Wakeley spoke up strongly for use of the Oxford Decimal Classification of Forestry by the Forest Biology Committee. There was no disagreement concerning this point; it is understood that the committee will consider seriously the Oxford system of classification as and when a decision needs to be made.

Report of Subcommittee No. 1 on Bibliography. In the absence of Philip R. Larson, chairman of Subcommittee 1 on Bibliography, Chairman Stevenson read the report of the subcommittee. Larson's report noted that a total of 975 pertinent references have been accumulated for inclusion in the bibliography, with 655 of these having been assigned to subcommittee members for abstracting. In addition the publishers of *Forestry Abstracts* have granted permission for the subcommittee to lift up to 200 abstracts from their publication. Of the remaining 120 references, many are older foreign papers, mainly German and Scandinavian.

Larson's report noted that none of the committee members has turned in additional references gleaned from literature reviews of papers being abstracted. He asks that such references, if they have been compiled, be sent to him for checking and inclusion in the master list. The Seattle meeting has been set as a positive deadline for all of the abstracting that is to be done by Subcommittee 1. At the Seattle meeting, Subcommittee 1 will make final arrangements for publication and review of its report.

Subcommittee 1 received a $100 TAPPI grant for expenses incurred in carrying out the preparation of a "Selected Annotated Bibliography on Environmental and Genetic Influences upon the Quality of Trees for Pulpwood." Of this amount, $51 has been spent to date for Keysort cards, and $0.45 has been spent for postage. A balance of $48.55 remains.

Wangaard asked a general question about the machinery for continuation of the bibliography that Subcommittee 1 is preparing at present. Wakeley pointed out the value of Keysort cards for continuation of such a bibliography, and reminded the committee that Subcommittee 1 is using Keysort cards in its work. Continuation of the excellent work of Subcommittee 1 met with general approval, but formal action was not considered necessary at this time.

Report of Subcommittee 2, on Tests and Quality Objectives. In the absence of Joranson, the chairman of Subcommittee 2, Pollock reported on the work of the Subcommittee over the past year. He first referred to the new members of the Committee—Thode, Wangaard, and Mayer—and the resignations of Lannan and McLaurin.

The principal portion of Joranson's report, as presented by Pollock, consisted of the events and minutes of a subcommittee meeting on Jan. 22, 1960, in Chicago, Ill. This meeting was called to review and revise previously prepared digests of selected wood and fiber properties with regard to their effects on processing and the subsequent properties of paper and paperboard. The list of wood and fiber properties that were reviewed is as follows:

1. Wood density or specific gravity
2. Proportion of springwood and summerwood
3. Growth rate
4. Chemical composition of wood
5. Fiber length (average and distribution)
6. Fiber diameter (average and distribution)
7. Cell wall thickness (average and distribution)
8. Fibrillar angle
9. Fiber strength as it exists in the wood
10. Bonding strength, fiber to fiber
11. Knotwood
12. Reaction wood
13. Proportion of nonfibrous elements in the wood.

Minutes of the Chicago meeting containing digests of these properties are being mailed to all members of the Forest Biology Committee.

Driver commented on No. 13, Properties of Nonfibrous Elements in Wood. The section covering this property was prepared by Thode and was read to the committee by Pollock. Driver suggests that the title of this section be changed to "Properties and Classification of Wood Elements." No objection was raised to this suggested change. Chairman Stevenson then asked Pollock to pass Driver's suggestion on to Subcommittee 2 for full Subcommittee action.

Thode is to present the report of Subcommittee 2 in the form of a paper at the Seattle meeting of the Forest Biology Committee this coming summer. It had been hoped that this paper could be published jointly in *Tappi* and the *Journal of Forestry*, but this may prove difficult. *Tappi* can publish the paper shortly after it is presented. The *Journal of Forestry*, however, may not be able to publish concurrently with *Tappi*, principally because of a tremendous backlog of papers. After considerable discussion, Besley suggested that the chairman of the Forest Biology Committee get in touch with Arthur Meyer, editor of the *Journal of Forestry*, urging joint publication of the report of Subcommittee 2 in *Tappi* and the journal if possible, a thorough abstract in the journal as a second choice, and finally a thorough review of the report as it appears in *Tappi* if neither of the first two suggestions are possible. Besley also suggested that the report of Subcommittee 2 be reviewed for *Forestry Chronicles*.

As a final item in connection with the report of Subcommittee 2, Mayer asked that members of the Forest Biology Committee study over the write-ups on the 13 properties that they will receive in the minutes of the subcommittee meeting. The subcommittee would like the opinion of foresters and geneticists on the committee particularly as to quality and depth of treatment of the write-ups. If the 13 properties have not been covered thoroughly or deeply enough, Subcommittee 2 can dig deeper in preparing digests of them. Mayer emphasized that the present digest was deliberately kept as short and simple as possible; he fears that it may be too elementary, however, and mentioned that the subcommittee would rather not publish its report if this is the case.

In connection with publication of papers, Driver commented on the lack of forest biology representation on the *Tappi* Editorial Board. Winchester of the TAPPI staff, said that a forest biologist should definitely be on the editorial board if enough articles on forest biology are submitted to the magazine. In concluding this discussion, Driver moved and Dorman seconded a motion that the committee instruct Chairman Stevenson to offer the *Tappi* Editorial Board the editorial services of the Forest Biology Committee in the preparation and publication of articles dealing with forest biology. The motion carried unanimously.

Report on Plans for the Technical Meeting at Seattle in August. Rolland F. Sultze, who represented Robert J. Seidl at the meeting, brought the committee up to date on the plans for the technical meeting to be held in Seattle, Wash., this coming August. Seidl is general chairman for the conference, which is scheduled to start on Wednesday, August 24, with papers continuing through Friday, August 26. On Saturday, August 27, there will be an optional field trip. Seidl anticipates an attendance of approximately 300 at this open meeting, and preregistration is to be required in order to facilitate handling this number. Headquarters for the meeting will be the Doric-New Washington Hotel in Seattle. Sultze outlined the specifics of the meeting as follows:

1. Wednesday, August 24
   a.m.—Meeting of Subcommittees 1 and 2
   p.m.—Introductory general session
2. Thursday, August 25
   a.m.—Evaluation of wood properties
   p.m.—Panel on "Can Genetic Improvement of Wood Properties Keep Pace with Technological Change?"
3. Friday, August 26
   a.m.—Variation in wood properties
   p.m.—Influence of wood and fiber properties on pulp and paper characteristics

There will be either a luncheon or an evening banquet on Thursday, August 25. Sultze says that a slogan or theme for the conference is still needed, and he or Seidl would like suggestions for a luncheon or dinner speaker. Finally, the suggestion was made that we invite a Canadian paper on wood characteristics and their effect on paper characteristics. Sultze is to carry these suggestions back to Seidl.

Chairman Stevenson read a letter from Dr. A. L. Orr-Ewing, inviting members of the Forest Biology Committee to a meeting of the Canadian Committee of Tree Breeding on August 21–23 at the Forest Experiment Station, Lake Cowichan, Vancouver Island. Chairman Stevenson remarked that the entire membership of the Forest Biology Committee would be fully informed of this invitation from Dr. Orr-Ewing. Finally, it should be mentioned that the TAPPI Forest Biology Committee meeting immediately precedes the meeting of the World Forestry Congress, which is to convene in Seattle, Wash., on Monday, Aug. 29, 1960.

Possible New Committee Projects. Along the line of new committee projects, Besley suggested that the committee become active in phases of forest biology other than genetics that affect wood characteristics and, therefore, pulping and papermaking. He prefaced this suggestion with a brief review of the present forestry situation in much of Canada, which relegates genetics to a lesser position, comparatively speaking, the related fields of forest science. He noted that silvics, silviculture, plant physiology, etc., were parts of the forest biology complex; and that possible relationships between these and pulping and papermaking might be as strong and possibly more evident than is the case with forest genetics.

Most of the committee members were in favor of Besley's ideas and suggestions that definitive work regarding wood properties *as they exist rather than as they can be developed* be started. Pollock remarked that the work of Subcommittee 2 is in line with Besley's recommendations. After considerable discussion between Besley, Pollock, Mayer, Driver, Stevenson, and others, the topic was closed with the understanding that it would be brought to the attention of the committee membership through these minutes, and perhaps discussed more fully by the Committee in August.

New Business. Dr. Lewis announced that TAPPI has allocated $62,500 for support of committee projects this year. This amount is slightly larger than in 1959. Dr. Lewis noted that the atmosphere of the Executive Committee is good for receiving requests for research money. These requests are considered by the Executive Committee on April 1 and October 1 of each year; therefore, requests for funds should be submitted prior to these dates.

There being no other new business, Chairman Stevenson declared the meeting adjourned at 11:57 a.m.

J. W. Johnson, *Secretary*

Testing Division

Chemical Methods Committee

The Chemical Methods Committee met for two 3-hr. sessions on Feb. 22 and 23, 1960, at the Hotel Commodore, New York City, with the following people in attendance at one or both sessions:

Robert MacClaren, Eastman Kodak Co., Rochester, N. Y.
F. B. Sutphin, West Virginia Pulp & Paper Co., Covington, Va.
R. H. Ramsay, Brown Co., Berlin, N. H.
B. W. Forshee, National Bureau of Standards, Washington, D. C.
A. R. Reid, Hercules Powder Co., Wilmington, Del.

Chemical Methods Committee

C. P. Kool, West Virginia Pulp & Paper Co., Covington, Va.
J. F. Saeman, Forest Products Lab., Madison, Wis.
M. A. Millett, Forest Products Lab., Madison, Wis.
H. A. Smith, Mead Corp., Chillicothe, Ohio
J. C. Cousins, Penobscot Chemical Fibre Co., Old Town, Me.
Sterling Bailey, North Carolina Pulp Co., Plymouth, N. C.
L. T. Eby, Enjay Co., Inc., Elizabeth, N. J.
J. E. Tasman, Pulp & Paper Research Institute of Canada, Montreal, Que.
Earl S. McColley, Celanese Fibers Co., Cumberland, Md.
K. A. Kuiken, Buckeye Cellulose Corp., Memphis, Tenn.
W. K. Wilson, National Bureau of Standards, Washington, D. C.

T 408 Rosin in Paper and Paperboard. A revised method was submitted by A. R. Reid. A few minor changes were suggested, and when these have been made the method will be sent out for letter ballot. The revised method includes the Halphen-Hicks procedure for identifying rosin in paper and paper products. It was suggested that peroxide-free ether be specified as a safety precaution.

Molecular Chain-Length Distribution. The Chemical Methods Committee has never been particularly active in this field, and a method has never been prepared. As an ASTM D 23 method is about ready, we hope to inherit this as a possible TAPPI method.

T 435 Hydrogen Ion Concentration of Paper Extracts. Two procedures are presently available under T 435 for the determiniation of the pH of water extracts of paper, a cold-extraction method and a hot-extraction method. It has been suggested that these procedures be separated into two methods with different numbers, and this has been carried out by Sterling Bailey. No basic changes have been made in the procedures. A 5-g. specimen has been substituted for the 1-g. specimen.

As we are cooperating with the Scandinavian testing group, these methods will be sent to Dr. Bethge for comment before further action is taken.

A report will soon be available on the use of special electrodes for determining the surface pH of paper. Unfortunately, this was not mentioned at the meeting, but the report should be available to the task group within two months.

T 428 Water Soluble Acidity or Alkalinity of Paper. This method consists of measuring the amount of acid or alkali extracted by water at steam-bath temperature. It has been proposed that a cold-extraction method should also be available. Sterling Bailey submitted a revision of T 428, and a cold-extraction procedure which would be given a new number. The acidity or alkalinity will be reported from both methods in terms of milliequivalents per 100 g. instead of per cent Na_2O or SO_3.

T 230 Cupriethylenediamine Disperse Viscosity of Pulp. C. H. Lindsley, chairman of the ASTM D-23 Section on Disperse Viscosity, has prepared a method that is now under consideration by D-23. A copy of this method was turned over to Dr. MacClaren who volunteered to communicate with Dr. Lindsley concerning the possibility of using this as the basis for a revision of T 230.

It was agreed that the falling-ball procedure should be left to the Routine Control Committee.

T 226 Specific External Surface of Pulp. Dissatisfaction with this method was indicated. Both Dr. Clark and Dr. MacClaren have work in progress on methods for the determination of external surface, and they agreed to look further into the possibility of preparing a TAPPI method on the basis of their work.

T 418 Organic Nitrogen in Paper. A revised method was sent out for letter ballot, and several favorable ballots have been returned. The only point of disagreement is the catalyst. As so many different catalysts are available, complete agreement on this point is unlikely.

T 419 Starch in Paper. A revised method, based on the colorimetric determination of the starch-iodine complex, has been voted favorably by our committee and is now ready to be sent to the Standards Committee.

Our proposed colorimetric method was not favorably received by the Testing Committee of the Australian Pulp and Paper Industry Technical Association. They have been using a method based on the hydrolysis of starch to dextrose, using perchloric acid, which is then determined with the anthrone reagent.

As the present TAPPI Standard, T 419 m-45, is so unsatisfactory, it was agreed that the colorimetric method should be pushed through as soon as possible and a task group activated to compare the colorimetric method with the Australian method.

T 406 Reducible Sulfur in Paper. A revision of this method has been approved by letter ballot and is ready for submission to the Standards Committee. This method is not entirely satisfactory, but there is no one available at present who can do the development work necessary to ensure a reliable method. Eastman Kodak uses a method based on the development of photographic paper under standard conditions. Dr. MacClaren agreed to supply copies for distribution to the Chemical Methods Committee.

T 202 Chlorine Consumption of Pulp. It was suggested that this method either be withdrawn or included in the book of standards for historical reasons only.

T 215 Copper Number of Pulp and *T 430 Copper Number of Paper and Paperboard.* The copper number method has been used for many years as an empirical measure of the reducing groups in cellulose. One member of the committee told us that his company had used copper number as an indication of the aging quality of paper as measured by exposure to an ultraviolet lamp (Uviarc) for a definite period. With the advent of new bleaching methods, exposure to the Uviarc may give entirely different results on some papers. Whereas a copper number in excess of 0.5 formerly resulted in unsatisfactory performance upon exposure to the Uviarc, paper made from a pulp bleached with chlorine dioxide may have a copper number in excess of 2.0 and still pass the Uviarc exposure test.

It was agreed that the copper number test itself was not at fault—newer cooking and bleaching processes result in modifications in the anhydroglucose ring that upset the interpretations of the present empirical tests. *Completely new and different test methods are required that will give information on the functional group content as well as the location of these functional groups in the anhydroglucose ring.* As a project of this type could be expected to require approximately 20 man-years of work, the solution is completely outside the scope of the Chemical Methods Committee and beyond the effort that could be exerted with the aid of a TAPPI grant.

Wet-Ashing Prior to the Determination of Inorganic Pulp Constituents. Methods are becoming available for the

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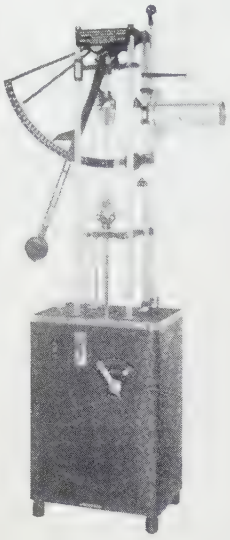

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determination of metallic constituents in pulp and paper. Many of these procedures remove the organic matter by burning in a furnace or over a gas burner. However, data in the literature and unpublished information volunteered during the meeting show conclusively that wet-ashing is necessary in most cases to ensure quantitative results. Dr. Kuiken agreed to head up a task force to study the over-all problem.

TAPPI Reference Pulp. The TAPPI reference pulp that is used as a freeness standard has been analyzed in several laboratories by several TAPPI methods to ascertain its usefulness as a reference pulp for chemical testing. This program was executed by John Tasman, and a report was distributed to the committee about a week before the meeting. Data by the following procedures were obtained:

T 203 m-44	Alpha-Cellulose
T 203 m-58	Alpha-Cellulose
T 204 m-54	Ether Solubility
T 204 m-54	Alcohol Solubility
T 211 m-54	Ash
T 212 m-54	1% NaOH Solubility
T 215 m-50	Copper No.
T 223 m-58	Pentosans
T 229 m-45	Water-Soluble Sulfate
T 229 m-45	Water-Soluble Chloride
T 230 m-50	CED Viscosity—Ballfall
T 230 m-50	CED Viscosity—Capillary
T 235 m-58	18% Caustic Solubility
T 235 m-58	10% Caustic Solubility

The report is not yet in publishable form, but the following tentative conclusions may be drawn:

1. The between-laboratory variability is *much* greater than the within-laboratory variability.
2. It might be possible to reduce the between-laboratory variability with a reference pulp.
3. It appears that some of the TAPPI methods should be more closely defined, *or* the participants did not follow the TAPPI methods closely enough, or both.

The publication medium for this report has not been selected.

Format of TAPPI Methods. The group discussed at some length the philosophy of TAPPI standard methods, how well the procedures should be defined, for whom the methods are written, how thoroughly the reactions should be explained, how extensively precautions should be spelled out, etc. Mr. Tasman reviewed the format of Canadian standards, which include sections on procedure, explanations, and precautions. Mr. Tasman agreed to submit a memo for distribution to the Chemical Methods Committee and to send along an example of a Canadian standard. After the views of the entire committee are obtained, the information will be synthesized into a report to be submitted through channels to TAPPI headquarters.

Paper Testing Committee

The Paper Testing Committee met Feb. 22, 1960, during the Annual TAPPI Meeting. Chairman L. Price presided, and 18 members were present. The agenda covered reports by subchairmen and discussion of the following methods: T 400, T 403, T 404, T 410, T 409, T 414, T 426, T 423. T 460, T 453, T 437, T 457, T 447, T 479.

An election of new officers followed:

W. P. Dohne, *chairman*
G. A. Schrag, *vice-chairman*
W. F. Bachelder, *secretary*

The meeting closed with thanks to L. Price for serving well as committee chairman for the past five years.

W. P. Dohne, *Secretary*

Paper Testing Committee

Eleventh Testing Conference
of the
Technical Association of the
Pulp and Paper Industry

Pantlind Hotel, Grand Rapids, Mich.
Sept. 27–29, 1960

Note on the Performance of the Handle-O-Meter as a Physical Test Instrument for Measuring the Softness of Paper

T. W. LASHOF

The Handle-O-Meter is described briefly, and the literature on the softness of paper is cited. The results of a short series of studies, including two interlaboratory tests, are reported. When the Handle-O-Meter is used to measure the softness of toilet tissue, the "instrument" error is not more than 4% (coefficient of variation). Roll-to-roll and position-along-roll variabilities are significant. Attention must also be given to the relative humidity and to the slot width and centering and alignment of the penetrating arm of the Handle-O-Meter.

THE Handle-O-Meter is an instrument (*1, 2*) for the measurement of the "hand" on "handle" of a sheet material, such as a textile or paper. The instrument includes a table or platform with a slot extending across the platform from front to back. The specimen to be tested is centered over the slot, and a penetrating arm is pivoted in the body of the instrument in such a way that it pushes the specimen into the slot to form a U-shaped loop. The force of resistance presented by the material as it enters the slot is measured with the aid of a strain gage and is indicated on an electric meter.

The force of resistance is thought to be composed of two parts: bending resistance and frictional resistance. The flexural rigidity of the material will result in the development of a bending resistance which will depend on the width of the slot. The surface roughness of the material will develop a frictional resistance when the material is dragged over the square edge of the slot. The subjective judgment of "handle" or "softness" seems to depend upon a combination of these two properties of the material. Thickness, compressibility, and basis weight may also affect the judgment of softness.

Several other instruments purport to measure softness. Since stiffness (i.e., flexural rigidity) is one of the most important components of softness, stiffness and softness are often confused and stiffness testers are sometimes called softness testers. A comparative study of four "softness" testers (*3*), including the Handle-O-Meter, has been presented. The TAPPI Tentative Standard T 451 m-45 gives a formula for computing softness from stiffness, basis weight, and thickness (*4, 5*).

The softness of soft papers, such as facial tissue, napkin stock, or lightweight toweling, has also been measured as the force necessary to crumple a loose wad of a definite area of specimen into a definite volume (*6, 7*). Still another procedure, very similar to that of the Handle-O-Meter, has been described recently (*8*), in which a sheet of the specimen to be tested is placed over a circular hole in a platform, and spheres of progressively increasing weight and of like diameter but of less size than the hole are placed one after another on the sheet until the weight of a sphere is sufficient to drive the sheet a predetermined distance into the hole.

T. W. LASHOF, Member, Paper Testing Committee.

Of these several procedures for determining the softness of material, that using the Handle-O-Meter has been reported to be the most suitable for control testing in the mill (*3*). This is because the measurement is quick and is little influence by the operator. For these same reasons the instrument was suggested for use in testing conformance of toilet tissue with Federal specifications (*9*). A short series of studies, including interlaboratory tests, was therefore made to investigate its performance in this application.

INTERLABORATORY TESTS

At first there appeared to be considerable instrument-to-instrument variability. However, much of this was traced to improper adjustment of the instruments. First, because the instrument frame and base are somewhat flexible, the instrument should be securely bolted to a sturdy table. If this is not done, the relative position of the slot and of the penetrating arm as it enters the slot can easily be changed by a twist in the instrument frame. Next, the slot width should be accurately set to the recommended slot width (0.250 in. for toilet tissue), not just in the middle or one end of the slot but at both ends. Also the penetrating arm should be visually parallel to the slot edges and centered in the slot. Both the slot width and the centering of the penetrating arm in the slot are very important. Finally, the instrument should be adjusted and the calibration checked according to the manufacturer's instructions. When the instruments are properly adjusted, the major variability from instrument to instrument for a particular type of material is probably associated with differences in humidity conditions.

Table I shows averages for several instruments and materials. (These instruments were located in different laboratories.) It can be seen that some laboratories are consistently higher than others for all materials even by a factor of two. The laboratories did not all use the same slot width despite instructions calling for a definite slot width.

A second interlaboratory test in which adjustment of slot width, alignment and centering of penetrating arm, and electrical adjustment were strongly emphasized, yielded the results presented in Table II. It can be seen that there is considerable improvement, but that one laboratory is still very much out of line. This laboratory reported later that their

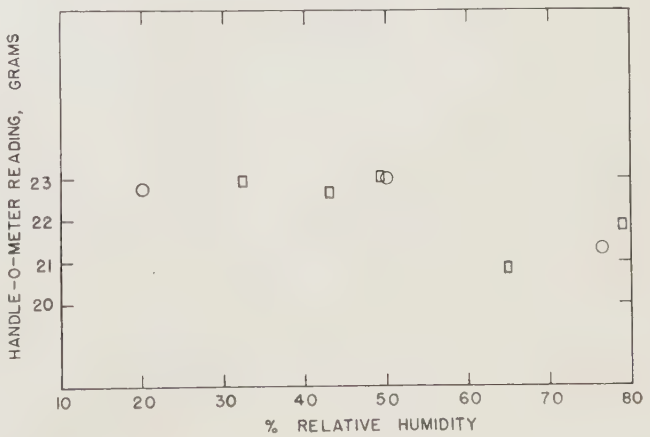

Fig. 1. Effect of relative humidity. The circles and squares are results from two separate experiments using material 7 in the cross direction

Table I. First Interlaboratory Test. Average Handle-O-Meter Readings[a] for Several Laboratories and Several Single-Ply Toilet Tissues

Direction	Material code no.	Laboratories 1	2	3	4	5	6
Machine	7	5.09	4.84	4.31	1.78	4.57	4.74
	4	10.39	9.81	7.25	4.22	9.92	9.59
	10	21.24	20.03	13.47	9.66	20.19	19.14
	11	24.81	23.09	16.09	10.81	23.71	22.16
Cross	6	20.57	18.41	12.91	9.50	19.50	...
	7	21.26	20.22	14.66	10.00	20.59	...
	9	25.99	26.41	18.41	11.78	25.45	...
	5	35.32	29.22	21.32	15.22	32.91	...
Slot width, mm.		5.0	4.9	6.4	6.4	5.0	6.4
Temperature, °F.		73	73	73	70	70	73
Relative humidity, %		50	50	50	29	50	50

[a] Each entry in the table is the average of 16 readings. Each reading is the result, in grams, for the simultaneous testing of two sheets side by side.

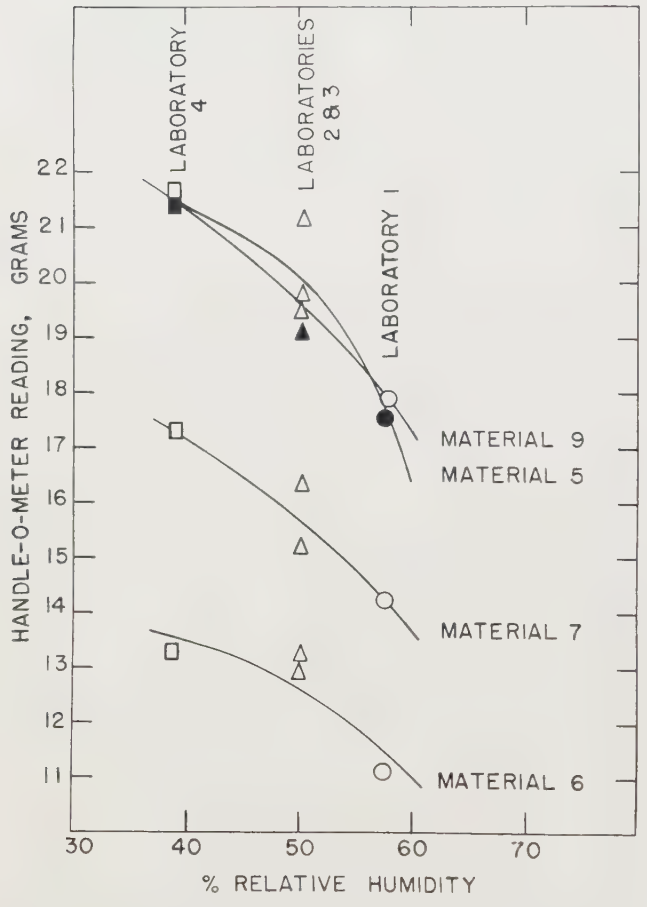

Fig. 2. Laboratory results arranged according to relative humidity

Laboratory 1—circles; laboratories 2 and 3—triangles; laboratory 4—squares

Handle-O-Meter "was not functioning properly" at the time of the tests. The differences between the other laboratories could probably be accounted for by humidity conditions.

A machine-direction test is one in which the machine-direction fibers are bent by the penetrating arm. A machine-direction specimen, as used in the tests reported here, consisted of two sheets of tissue placed side by side over the slot with the widths in the slot direction. A cross-direction test is one in which the cross-direction fibers are bent by the penetrating arm. A cross-direction specimen as used in the tests reported here consisted of a single 9-in. length of tissue placed over the slot with the length in slot direction.

EFFECT OF RELATIVE HUMIDITY

Figure 1 illustrates the effect of the relative humidity in the testing room on the Handle-O-Meter reading. It can be seen that for the material shown the effect is appreciable at high humidities.

In Fig. 2, the data of Table II are plotted against the average relative humidities reported by the laboratories. Laboratory 5 is omitted from this plot because of its reported difficulties with the instrument. The data are very meager, but examination of Fig. 1 and 2 does seem to suggest that relative humidity differences could explain most of the differences between laboratories 1 to 4 in the second interlaboratory test.

EFFECT OF SLOT WIDTH AND OF CENTERING OF PENETRATING ARM

The variation in slot width shown at the bottom of TableI might explain some of the differences found between laboratories. Figure 3 illustrates the effect of the variation in slot width. This, of course, is the result that one might expect, and it is of the right magnitude to explain much of the differences between laboratories. However, there is still a residual amount of variation which cannot be explained either by slot width differences or by relative humidity differences.

It appears that any lack of alignment and centering of the penetrating arm in the slot can also have an important effect on the results. Figure 4 shows the several experimental conditions used to investigate this effect, and the average results for each condition. It will be noted that a slight lack of parallelism of the slot edges or lack of alignment of the penetrating arm with the slot edges is not too important as long as the penetrating arm is centered in the slot. Lack of cen-

Table II. Second Interlaboratory Test. Average Handle-O-Meter Readings[a] for Several Laboratories and Several Single-Ply Toilet Tissues

Direction	Material code no.	Laboratories 1	2	3	4	5
Cross	6	11.09	12.85	13.20	13.25	18.47
	7	14.20	15.15	16.25	17.25	23.12
	9	17.84	19.65	19.45	21.45	27.74
	5	17.56	19.00	21.25	21.40	28.04
Slot with, mm.		6.4	6.4	6.4	6.4	6.4
Temperature, °F.		77	73	70	65	73
Relative humidity, %		57.5	50	50	38.5	50

[a] Each entry in the table is the average of 10 readings. Each reading is the result, in grams, for the simultaneous testing of two sheets side by side.

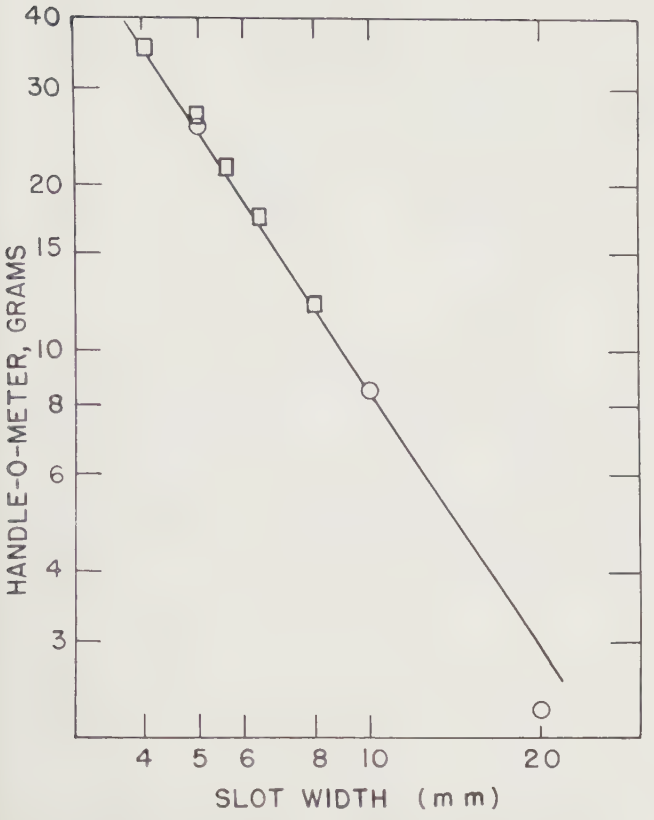

Fig. 3. Effect of slot width. The circles and squares are results from two separate experiments using material 11 in the machine direction

tering gives an appreciable effect that is equivalent to using a narrower slot.

EFFECT OF POSITION OF SPECIMEN AND EFFECT OF SIDE OF SPECIMEN FROM WHICH TEST IS MADE

According to the manufacturer, tests of many materials will not repeat if readings are taken in the same spot. This was verified for toilet tissue, and means that the test causes a change in the material being tested. In order to check a reading on a specimen, it has therefore been suggested that another spot be tested. However this leads to another difficulty.

Figure 5 shows the variation in the Handle-O-Meter value with the position of the specimen on the platform. A maximum reading is obtained when the specimen is carefully centered over the slot, but the reading falls off appreciably if the measurement is made near an edge of the specimen. Examination of a specimen under test shows that the portions of the specimens just on either side of the slot are raised as the portion over the slot is pushed down into the slot. When the measurement is made near an edge, the whole edge may be raised from the platform. It therefore appears that the basis weight of the specimen has an appreciable effect on the Handle-O-Meter reading. In order that this not enter as a source of variability in the measurements, a narrow specimen

Table III. Precision of Results. First Interlaboratory Test

Direction	*Material code no.*	*Average,[a] g.*	*Standard deviation, g.*	*Coefficient of variation, %*
Machine	7	4.81	0.23	4.9
	4	9.93	0.49	5.0
	10	20.15	1.18	5.8
	11	23.44	1.03	4.4
Gross	6	19.49	1.71	8.7
	7	20.69	0.85	4.1
	9	25.95	2.91	11.2
	5	32.48	2.90	8.9

[a] Omitting laboratories 3 and 4.

	DISPLACEMENT(ε) MM	HANDLE-O-METER GRAMS
SLANT	+0.4	25.4
	−0.4	24.6
TAPER	+0.4	26.3
	−0.4	25.9
SHIFT	− 1.0	35.4
	−0.6	29.0
	0.0	25.8
	+ 0.2	25.6
	+ 0.6	29.9

Fig. 4. Effect of alignment and centering of penetrating arm

Slant: Penetrating arm is at an angle with the slot. Taper: Slot is wider at one end than at the other, but penetrating arm is centered. Shift: Penetrating arm is parallel to sides of slot but not centered in slot. The standard error of the averages shown in the figure is 0.33 g.

such as toilet tissue should be carefully centered over the slot.

The side from which the test is made does not appear to be important for the toilet tissue tested except as it may be related to the position effect. Thus it is the curvature of the specimen as taken from the roll rather than a wire-felt side difference that shows up in the test of a single-ply toilet tissue. It is recommended that all tests be made with the side that was inside on the roll facing up.

PRECISION

The precision of the Handle-O-Meter method for the measurement of the softness of toilet tissue depends to a considerable extent on the variability of the toilet tissue. Thus the limiting factor in determining the value of a lot of material is usually the roll-to-roll variability. Also the variation along a roll is greater than that assoicated with adjacent specimens of the roll. This lack of uniformity must be taken into account in any sampling plan.

Table III gives the precision of softness values for several materials after roll-to-roll and position-along-roll variabilities have been eliminated. This is the nearest we can come to "pure" instrument error. However, even here there is a difference in precision between results obtained with different materials. It appears that for a particular instrument (and observer) the "pure" instrument error will not be greater than 4% (coefficient of variation). Because of the limited number of materials available for this study, it is not possible to decide whether the larger variation in the cross direction is generally true or a chance effect.

The precision values obtained from the first interlaboratory test were verified by several within-one-laboratory studies. Table IV shows the results of one such study. Similar results were obtained in the second interlaboratory test, Table V. In this second interlaboratory test five adjacent specimens in a roll were considered to form a "block." The five specimens of a block were assigned at random to the five laboratories. Ten blocks from a single roll were used for each material. As previously mentioned, the variability within a

Table IV. Precision of Results. Comparison of 5.0-Mm. Slot Width with 0.25-In. (6.44 Mm.) Slot Width

Direction	*Material code no.*	*Coefficient of variation, % 5.0 mm.*	*0.250 in.*
Machine	7	4.2	3.6
	4	5.4	4.9
	11	3.8	4.2

Table V. Precision of Results. Analysis of Variance of Second Interlaboratory Test[a]

Source of variability	Mean squares Mat. 6	Mat. 7	Mat. 9	Mat. 5	All	Components of variance
Laboratories	10.42	17.52	21.82	34.4	73.473[b]	1.761
Materials					474.928	...
Lab. × mat.					3.562	0.054
Blocks within mat.	9.02	3.93	2.85	7.02	5.705[b,c]	0.671
Lab. × bl. w. mat.	3.841	0.713	3.601	3.934	3.022[c]	3.022
Std. dev., g.	1.96	0.84	1.90	1.98		
Averages, g.	12.60	15.91	19.60	19.80		
CV, %	15.6	5.3	9.7	10.0		

[a] Omitting laboratory 5.
[b] Significant at 1% level.
[c] Pooled values.

roll (i.e., block-to-block variability, labeled "Blocks within Mat." in Table V) is appreciable. The component of variance for laboratories would probably be considerably smaller if all laboratories operated at the same relative humidity.

"Lab. × Roll" interaction was significant in the first interlaboratory test. Therefore "Lab. × Mat." interaction might be expected to be significant in this second interlaboratory test, since rolls and materials are confounded (i.e., there was only one roll per material). The fact that it is not significant is probably associated with the better agreement between laboratories. The absence of interaction is desirable, since if there is no interaction, only a single standard is needed to adjust for differences between laboratories.

GENERAL CONCLUSIONS

This short series of studies indicates that the slot width and the centering of the penetrating arm in the slot each have an appreciable effect on the Handle-O-Meter reading. On the other hand, a slight lack of parallelism of the slot edges or lack of alignment of the penetrating arm with the slot edges is not too important as long as the penetrating arm is centered in the slot. Relative humidity appears to have some effect on the reading.

For a narrow specimen such as toilet tissue ($4^1/_2$ in. wide) the centering of the specimen over the slot is important. For single-ply toilet tissue the Handle-O-Meter appears to be sensitive to the curvature of the specimen as taken from the roll rather than a wire-felt side difference.

When the Handle-O-Meter is used to measure the softness of toilet tissue, the "instrument" error is not more than 4% (coefficient of variation). Roll-to-roll and position-along-roll variabilities are significant.

A much more extensive study would be required before the instrument could be recommended for use in a TAPPI standard method for softness. In the more extensive study the Handle-O-Meter should be compared with other instruments which purport to measure softness. Facial tissue, lightweight toweling, napkin stock, and other materials for which softness is an important physical property should be included in the study in addition to toilet tissue. Also more attention than was possible in this study should be given to the effect of relative humidity.

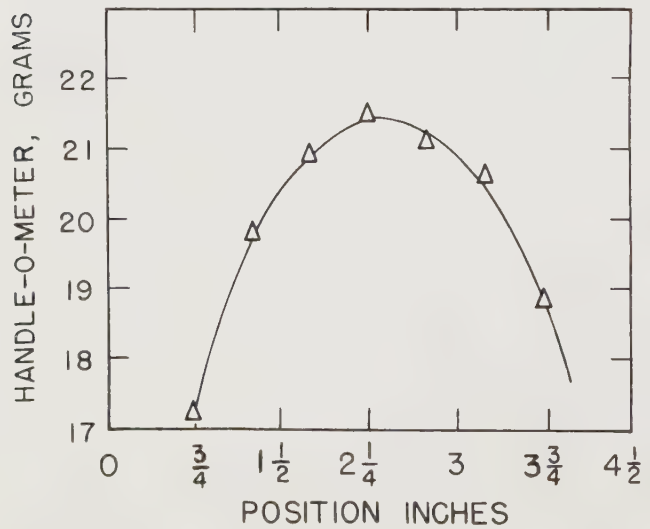

Fig. 5. Effect of position of specimen. Handle-O-Meter values shown are averages of 10 using material 7 in the cross direction. Positions are distance of penetrating arm from left side of specimen

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Eleventh

Testing Conference

of the

Technical Association

of the

Pulp and Paper Industry

Pantlind Hotel

Grand Rapids, Mich.

Sept. 27–29, 1960

Dissolving Pulps Session II

Proceedings of the 44th Annual Meeting of TAPPI, Feb. 23, 1959

The second Dissolving Pulps Session of the Technical Association of the Pulp and Paper Industry convened at 2 o'clock in the West Ballroom of the Hotel Commodore, New York, N. Y., Dr. Merle Heath, of The Buckeye Cellulose Corp., presiding.

Chairman Heath: The last item on the program this afternoon is a discussion around the outline which Ed Howard has gotten up with Dr. Kraessig. This was an idea that we had in the Dissolving Pulp Committee on a line of research that we might organize on a problem in cellulose. Ed will tell you about it.

E. J. Howard (Industrial Cellulose Research, Ltd.), Mr. Chairman, Gentlemen: Each of you has received a copy of the theme of this discussion, and I trust you have had time to study if not digest it.

I would like to point out that the topic of this discussion emanated a couple of years ago from one of our distinguished committee members, Dr. Morris Wayman of Columbia Cellulose. I do not see him here today, but perhaps he has solved the problem.

This hot potato landed in my lap and stayed there for a long time. I did nothing about it until a few months ago when I gave it to my colleague, Dr. Hans Kraessig, to expand it to something of an outline for committee discussion.

However, our well-meaning chairman thought it was still too hot to handle and decided to have a free for all and let the hot potato chips fall where they may, namely, into your collective laps.

To complete the research program which we have outlined, we know would require many thousands of man-hours for which, of course, neither the men nor the money are available. It is the object of the meeting this afternoon to suggest ways and means of boiling down the program to a more practical pocketbook size, that is, into one or two projects to start with having specific but limited objectives.

The question whether cotton linters or wood pulp is the preferred material for dissolving purposes has occupied the attention of cellulose chemists ever since wood pulp started supplanting linters some 30 years ago.

There is no doubt that in the early days, wood pulps fell far short of linters, both analytically and in end-product quality. After all, those early dissolving grades were actually no better than mildly upgraded paper pulps. But with the tremendous expansion of the dissolving field over the past 15 years and the strong competition from the synthetics, great advances have been made in improving wood pulp quality, so that today there are pulp grades on the market which, for all practical purposes, are equal to linters in quality and in use.

I do not wish to imply from this "know-it-all" attitude that we are about to flog a dead horse, but only to suggest that the urgency of the problem is not as great as it was, say, 10 years ago. I do feel that if we could uncover the basic differences between wood pulps and linters, we would be in a better position to improve our wood pulp technology for specific end uses.

Another excellent reason for pursuing this study is that the world production of linters in the next few years is expected to show little or no increase, so that wood pulp will have to fill the expanding demand for high quality dissolving cellulose.

I am quite confident the pulp industry will be able to do this very successfully. One of the first things to be considered in this basic study is to define what we mean by *standard* linters and *standard* wood pulp. There seems to be as many grades of linters as there are grades of dissolving wood pulp.

Now, I am quite ignorant of cotton linters manufacture, except what I have read in the textbooks. Apparently there are several raw linter grades available. You start with one or more of these. First, you cook them with caustic soda, at concentrations varying from 2 to 4%, at temperatures varying from 135 to 185°C. for times varying from 2 to 6 hr., thereby losing about a quarter of the original material. Then you multistage-bleach with chlorine, hypochlorite, or chlorine dioxide and demineralize with acid and centriclean. After that, you adjust fiber length with jordans and dry to moistures and at temperatures which vary according to the end use of the linters. Thus from the manner in which your raw linters are purified, I would judge they are subjected to much the same dangers of degradation that wood undergoes when converted to pulp.

Now, which one of these linter grades shall we use as our control in this proposed basic study? Perhaps the gentlemen of the chemical cotton trade, some of whom are present, will give us an answer.

Turning now to wood pulps, here again we are faced with a dilemma. Which wood, which cooling process, which bleaching and refining process shall we take as standard?

I will now ask my co-moderator, Hans Kraessig, for his remarks on the problem.

Dr. Hans Kraessig (Industrial Cellulose Research, Ltd.): Thank you very much, Ed, for calling on me. When you asked me some months ago to summarize my ideas for a basic research program intended to reveal more details than known at present on the differences between wood and cotton linters cellulose and their significance during their use as dissolving pulps, I was not at all aware of the fact that I might end up in front of such a distinguished audience.

I would like to say that, if I had known this, I would have drafted this outline in a somewhat different form, being more specific and bringing forward practical proposals.

I think that everyone present here will agree with me that any research program, in order to further our knowledge on the factors causing differences in performance of these two major raw materials in their further processing, has to be based on and started from what differences are known to exist and known to be important. We know that there are still differences in purity and in morphological fine structure. A further decision to be made by us will be to decide on how wide or how narrow we would like to put our aims. However, I think it should include efforts to advance our knowledge on the two questions on which the original outline has been based: significance of impurities and significance of differences in fine structure.

The literature is full of contributions to the solution of these two problems but nobody can claim that our knowledge of them is sufficient for complete answer. Please excuse me for not going into details to strengthen my argument because doing so would only be a repetition of textbook knowledge. I am quite willing to give details in reply to any questions.

Most of us are aware of what we know and how important a

more complete answer to these two questions would be for our industry. May I be allowed, therefore, to add something to the suggestion made by you, Ed, namely, to select standards for various grades of wood pulps and cotton linters pulps and to look into the existing differences in chemical composition and in fine structural characteristics in order to infer from these the processing properties of their derivatives. My suggestion is that, simultaneously, work should be outlined and recommended to universities willing to cooperate with us which will help us to obtain answers to the problem of the significance of the differences in composition and fine structure found as well as of the basic reasons for their detrimental or advantageous effects. In this connection, I specifically refer to the problems named under point A two, point B two, and point B three and B four of the outline.

I think that is all I have to say, and it is open for discussion now.

Mr. Howard: This is a panel discussion, and you are the panel. We are just moderators of some kind, and I would like everybody who has something to say to speak up. I prefer him to come up to the podium here where we have a microphone, and then everybody can hear what he is saying. I would ask him first to give his name and affiliation.

Although your remarks are being stenotyped, you will have an opportunity to censor them before publication. Please don't mind speaking off the cuff. Let your hair down and let the chips fall where they may.

Chairman Heath: I might just say before we get into this, that one of the reasons for bringing up this outline is that TAPPI has money for research grants. They don't have a great deal of money. You have to have a pretty good reason for asking for it, but that is one possibility here, that we would have a definite project which could be carried out at some recognized laboratory, if you find someone who is interested and has the time and facilities for doing it.

Mr. Howard: Perhaps I should start the ball rolling.

First get hold of a number of commercial wood pulp and linters samples typical of acetate and tire cord grades and give them a thorough physical and chemical checkup.

By "thorough," I mean not just gross analysis (which can be quite misleading, as most of you know) but go into such details as D.P. distribution, and the chemical composition of the various D.P. fractions, particularly xylan and mannan content of these fractions.

Dr. H. Haas (Zellstofffabrik Waldhof, Mannheim-Waldhof, Germany) over 10 years ago analyzed in this way a series of dissolving pulps obtained from different European woods by different processes and came up with some rather interesting deductions concerning not only the woods but also the pulps processes and some of their artefacts [*Wochenblatt für Papier fabrikation* 75: 45–48 (1947)].

Of course, we have to have a complete analysis of the ash and the extractables. We should also include measurements, as Dr. Kraessig has mentioned, of the crystallinity per cent of cellulose I and II and, of course, accessibility. I think it will be highly rewarding to analyze the various fiber length fractions obtained by mechanical classification of the samples. From this survey, certain patterns should emerge distinguishing the wood pulps from each other and from linters. I think this phase of the study would be best undertaken by an independent research institution.

B. Sutcliffe (Courtaulds (Canada), Ltd.): I think there are two fundamentally different ways you can go about this problem. One is to start from a position of ignorance and say that all we know is we have two different sorts of material which behave differently. They behave differently in processes which we don't understnad, so we can take a standard, which would have to be agreed on, on either side, and do a lot of investigational work.

There would be a lot of investigational work, and you wouldn't even know whether you were investigating the right things. At the end of all this, you would have a lot of analytical data, fundamentally, and you would have to then try to relate this analytical data to the differences in performance or product.

I wonder whether that type of approach wouldn't just be very time-consuming and whether you shouldn't start a little bit more with the process that you are going to put this thing into the start looking at how these things behave during the intermediate stages.

To take a simple example, in viscose, for instance, if you were to take well-filtered samples from which you removed the gross impurities, could you see differences between cotton and wood?

If you can't find differences there, the only differences to be expected is one of filtration, and that no longer needs investigation.

If you can say, "As far as we can see there are no differences in these two solutions, in their solution state," the morphology as a factor has been removed. This statement may or may not be true, and I think there is room for a lot of work in this area.

I think you have to go into this job from quite a broad background of knowledge of how we already know these things behave in our processes. Otherwise the thing would become extremely cumbersome to operate as a project and just go on and on.

Dr. Rapson (University of Toronto): I wonder if we shouldn't start out from what we can agree on and see what differences need to be investigated. About the point that was mentioned by the last speaker, I can recall some 10 years ago that we prepared a set of different rayons made from different materials, some from wood pulp, some from cotton, different kinds of cellulose, and they were submitted without any indication of where they came from to someone who was expert in the field of x-ray analysis. He was able to tell us which ones were made from cotton and which ones were made from wood pulp.

This seems to me to be sufficient evidence that whatever morphological differences there are, can be carried right through the entire process of dissolving and reprecipitating the generated cellulose. We can make the first assumption that there *is* some morphological difference.

On the other side of the fence is this fundamental point—I personally have come to the conclusion that there is no *chemical* difference between cellulose from wood and cellulose from cotton. That is to say, we have prepared cellulose from wood containing less than 0.1% of xylan and mannan [*Tappi* 42: 125 (1959)]. It seems to me this is sufficient evidence that the cellulose molecules are the same, both in cotton and in wood pulp.

It seems to me if we accept this (and maybe everybody won't!) that we can agree too that the differences arise from the nature of the impurities in both products.

We are used to talking about the impurities in wood, but there are impurities in cotton too. In fact, the very best cotton linters received still contain some impurities.

If this premise is accepted that the cellulose is the same in wood pulp, but the quantity and nature of impurities are different, we will all agree I think that the *quantity* of impurities is very much greater in wood pulp than in cotton; if that is so, then we remove these impurities in preparing a very pure cellulose from wood and we must leave the fiber structure different in some way.

We cannot remove materials without leaving holes, and for many years I have had the naive picture that the major differences between cotton and wood pulp lie in what we have left when we remove these impurities, that we have more surface in the wood pulp, and that we have fibers of different shapes and structures.

As far as dissolving pulp is concerned, as far as the end products are concerned, the rayon and cellophane films, of what-

ever they may be, seem to me to rest not so much on fiber structure as on the finer morphology of the fibers. I would suggest that we should agree on certain things now and see what needs to be investigated as far as the points on which we are not certain. This would cut the research program to a very small fraction of that presented.

CHAIRMAN HEATH: Certainly cellulose from wood is much more complex than from cotton. That is just the physical way in which it grows, and you have so many different functions in a wood structure than cotton, and that is bound to make a difference, unless you get down, as you say, to the fundamental cellulose molecule, which we very seldom do.

FRANK CHARLES (Industrial Cellulose Research, Ltd.): There is a body of knowledge which seems to be overlooked. I have to differ from Dr. Rapson a little here because I am trying to recall in my mind what the work is exactly, but I think it is by Rånby, and refers to hydrolysis to limiting D.P. He found that the ultimate crystallites from cotton linters were broader, and wood pulp showed a slow linear decrease in D.P. after the limiting value for linters was reached.

That means that chemically, or at least in the molecular architecture, there is possible a difference of crystallite formation, so that I wanted to bring this point out. Probably you are all aware of it. With regard, Howard, to your mention of these samples of rayon that were sent to Dr. Mark for identification, they were made from wood pulp and from linters. There were seven samples of which three were made from cotton linters, and these gave the x-ray diagrams from which the linters samples could be picked. The processing of the viscose and spinning was essentially the same. The linters tire yarns were picked out on the basis of better orientation and less amorphous halo. You could give these x-ray negatives to anybody, and they could pick out the three samples spun from cotton linters pulp.

Discussing this later with Dr. P. H. Hermans, we sent the negatives to him, and he rejected the idea that less amorphous halo had anything to do with the cotton linters. He was very strong about it and sent me a complicated proof.

However, it would look as though with x-ray diffraction you can pick out some differences between cotton linters and wood pulp rayons, and also with hydrolysis to limiting D.P. Wouldn't it be a good thing to check these two findings, these two concrete findings? Isn't that the first thing in any project, to check on what you already believe you know? This is a suggestion.

DR. KRAESSIG: I would like to answer one of these questions. I think it is an established fact that a difference in morphology and in the perfection of order exists between wood cellulose and cotton linters cellulose. Anyone who looks at x-ray diffractograms of wood pulps or cotton linters pulps will see the difference readily. In general, the reflections given by wood pulp cellulose are much wider, indicating either smaller crystallite size or lower degree of lateral order. Unfortunately, the methods we have for evaluating this and expressing it in comparable figures are not at all absolute. Recently, a very stimulating suggestion was made by Gjonnes and coworkers in Norway to analyze x-ray diffractograms of randomized semicrystalline polymers, such as cellulose, as summations of Cauchy distributions. We have checked this concept using a desk calculator and we agree that this is probably a sounder method. At present, we are considering the programming of a digital computer for this type of evaluation. The evaluations done so far show that the band-width of the reflections in x-ray diffractograms of wood pulps are in general about twice as large as those of cotton linters, which would mean that the crystallinity is lower or the crystallite size smaller for wood pulp cellulose. The basic question in this connection is whether this is a natural fact introduced by the presence of impurities which we remove during isolation of cellulose from wood, leaving a more heterogeneous system, or if the severe conditions during pulping destroy an originally more perfect structure.

To my knowledge, the literature does not contain enough information to answer this question. I think x-ray studies should be done to find out in what structural state cellulose exists in different plant species, and what changes take place during the removal of impurities and under the processing conditions used for isolation today. The results of such investigations would tell us how the final structure of a wood pulp in technical pulping is formed and how we may be able to do a better job on this. Some exploratory work we have done indicates that the original structure of the cellulose in wood is of relatively low perfection owing to the presence of lignin and hemicelluloses, and that the order improves during pulping as the impurities are removed at high temperature; this process is perhaps assisted by degradation. However, our work is not sufficiently advanced for a final statement on this. I can also say that we have checked the results of Rånby on the hydrolysis behavior of cellulose of various origins from pure curiosity and we agree with him that the D.P. of cotton linters levels out much more readily when the limiting D.P. of about 100 is reached than does the D.P. of wood pulp. Wood pulp in general not only degrades more quickly but the degradation proceeds beyond the limiting D.P. In accordance with the x-ray results this also suggests strongly the existence of smaller crystallites and perhaps of a wider distribution of crystallite sizes for wood pulps. We also do not know whether this is a natural factor whether this is something introduced in our processing of pulps from wood.

At this point I will add one further remark to illustrate the meaning of the second part of the outline we discussed here. Everyone of you knows the trouble which is caused by the presence of impurities such as mannan and xylan in wood pulps. I refer especially to cellulose acetate properties, such as false viscosity behavior and turbidity of cellulose acetate solutions. In the course of some work done recently we could show that when we centrifuge acetone solutions of cellulose acetate we can separate gel particles which are greatly enriched in mannan and xylan acetates. As a result of this treatment, structural viscosity as well as turbidity is improved and the properties are similar to those of cotton linters acetates. In this case, an observed difference in composition of the starting material is significant with respect to the properties of a resulting derivative. These studies also revealed that the detrimental effect of impurities on acetate properties results from very distinct differences in the solubility in acetone of cellulose acetate from that of xylan or mannan acetate. While we know a lot about the chemical structure of various hemicelluloses present in different wood species, I think we know too little about the differences between the properties of acetates or other derivatives made from hemicellulose and those of pure cellulose acetate or cellulose derivatives.

There are other factors, such as differences in the distribution of substituents, the presence of functional groups such as carboxyl groups together with polyvalent metal ions, which can also alter the flow behavior of cellulose acetate solutions.

MR. HOWARD: To me, one of the things to worry about is how far should wood pulp be purified to make it equal to linters. I do not subscribe to the theory that to make wood pulp equal to linters you have to purify it to 99% high D.P. cellulose.

If you gave pulp of this character of a papermaker, he would have a heck of a time trying to make good paper. If wood consisted only of lignin and cellulose, the tree would be so brittle as to fall down in the first wind storm. The natural hemicelluloses distributed, as they are, throughout the cellulose and lignin phases in wood, appear to be to act as plasticizers, and no papermaker would try to make a strong paper from a fiber which did not contain a fairly large amount of hemicelluloses.

I fail to see why a reasonable quantity of natural high D.P. hemicellulose cannot be left in the pulp without interfering with the yarn properties.

To satisfy the viscose industry, the poor dissolving pulp producer, instead of getting back half of his wood in the form of usable pulp, has to purify and repurify and end up with perhaps less than a third of his wood. He strives to get his alpha-cellulose good and high, in the 98 to 99% class, with D.P. well up to 800, 1000, or higher.

What is the first thing the viscose and acetate boys do? They degrade this carefully prepared pulp down to a lower level and pat themselves on the back if the D.P. of their finished product is above 300, which is like chopping up a nice piece of furniture to light a fire. It is like making a sow's ear out of a silk purse.

Dr. Lauer (University of Alabama): I agree completely with those remarks. If you try to improve it—and I am not talking about acetate rayon but I am talking about viscose grade—but if you try to improve the quality of your pulp, with respect to filterability by making, for instance, the alpha-cellulose and converting back by a careful treatment with water and acetic acid to a practically pure alpha-cellulose, and you try to now make viscose from this purified alpha-cellulose, which, according to analysis, is practically 100% alpha, it has no impurities any more, this viscose will filter as badly as the viscose made from the original pulp.

I wish just to mention that the only solution of the problems which we come across in this field is in the morphological study of the fibers, at least only in the viscose field, and that the analytical methods will lead us to nothing. I have studied the last 2 years' cotton linters from the same mill made in the same process in large scale from supposedly the same raw materials, at least bales from one big warehouse, and sometimes the batch is filtering satisfactorily and the next batch is not filtering at all.

I have studied those two linters viscose grade pulps, and I don't know why they are different. Analytically they are completely identical, only theone filters and the other doesn't filter; so there is in my opinion the part where we have to get in. Some 20 years ago in my institute we made very careful experiments with different wood pulps obtained either by the acid sulfite process, or we prehydrolyzed sulfate pulps from softwoods and hardwoods. We cooked pulps in our research installations to exactly the same analytical data, same viscosity, more or less the same distribution of D.P., and then we always found that if you compare them by the same standard viscose procedure, always the prehydrolysis sulfate pulp filters somewhat worse than the sulfite pulps, but always gave 2 km. higher breaking lengths than the others. This brought us to the conviction that primary fiber structural elements must go through the viscose into the final viscose fiber. We proved it then, it was published just at the end of the war in *Kolloid Zeitschrift*, by measuring the heat of dilution of a viscose, diluting with exactly the same sodium hydroxide thiocarbonate content.

The same viscose was diluted to near the limiting concentration, at which molecular dissolution is supposed to be complete, a ripening stabilizer was added and the viscose reconcentrated to the original concentration. Heat of dilution measurements on this viscose, which went through complete dissolution, showed remarkable differences in heat of dilution compared with the original viscose. It seems to prove that primary structural units from celluloses are retained in technical viscoses. This can explain why two analytically identical pulps from the same wood species and spun to a thread under identical conditions, give two fibers with definite different behavior owing to the pulping process [*Kolloid Zeitschrift* 112: 16 (1949)].

There is another very interesting point. There are two exceptions, Fortisan and Fiber "G" from du Pont. Except for that, all viscose fibers under whatever conditions you spin them—Hermans spins his isotropic filaments without any tension, just letting a viscose run into a spinning bath—you will always have around 40% crystallite and 60% amorphous. Why? Is cellulose doing it just because it likes 40% crystallite and 60% amorphous?

These are facts, and they can in my opinion be explained if we know more about the structure, the original structure of the wood, and cotton linter fibers from which we start.

Dr. Kraessig: May I add something? I know Dr. Hermans is one of the experts in this field. However, from our own work we know that differences in crystallinity of various rayons exist. They are in the order of at least 10%; normally, textile rayons have lower crystallinities than improved super tire yarn or meryl type rayon. There is one other fact to be mentioned. The analysis of the x-ray diffractograms gets extremely difficult with the new modified rayon fibers because they are not pure cellulose II. They contain varying amounts of so-called cellulose IV which makes the evaluation of x-ray diffractograms by separation into amorphous and crystalline scattering by interpolation under the diffraction curve very difficult. The concept of Gjonnes mentioned in one of my former remarks may present a way out of this difficulty.

In connection with the so-called structural memory of cellulose I would like to make one further remark. This so-called memory may not require, in my opinion, the presence of residues of an original structure but may just come as a result of a natural behavior or property of long chain molecules in general.

According to their chemical structure and to the flexibility of the molecule, a linear polymer tends upon reprecipitation to form aggregates the dimensions of which are given by the thermodynamic conditions prevailing during precipitation. At this point it may be added that from your work in connection with the specific properties of super rayons it is known that quite large differences in crystallite sizes can exist.

Chairman Heath: Dr. Kraessig was speaking a little while ago about mannan and xylan in acetate. Four or five years ago Dr. Bachlott at du Pont published a paper in which he related the tire cord fatigue resistance to the residual xylose, that is in the alpha-cellulose portion.

It seems that these noncellulosic, very small portions do have some function in the final properties of the product.

Dr. Kraessig: I can even go a bit further when you speak about tensile behavior. It is not only impurities such as mannose and xylose which affect the properties. We are at the moment doing some x-ray and molecular weight studies to obtain more knowledge about factors influencing tensile properties of fibers. The results we have obtained so far indicate that two factors are highly significant: the D.P. and the overall lateral order. Regarding the influence of the degree of polymerization, I think that the distribution of molecular weight should not be forgotten. We suspect that the number of loose ends in the less ordered regions is one of the factors affecting the strength of fibers. From this we conclude that low D.P. portions in a fiber are highly detrimental since they add to the number of loose ends in the amorphous regions. Thus, this factor should be considered in a discussion like this as well as the influence of impurities.

When you go back to pulp as a raw material and study the effect of its molecular weight distribution on the properties of the final product, such as viscose rayon, differences in molecular weight distribution of the raw material are only of significance for the properties of the final rayon when the degradation during the processing to rayon results in unusually high proportions of low D.P. matter. This can only be the case either when the original material has unusually large amounts of low D.P. material in relation to its average D.P. or when the raw material has been chemically damaged, such as by the introduction of weak links by oxidation, resulting in the formation of unusually high proportions of low D.P. matter during processing. In the study of the D.P. distribution of pulps it should be considered that pulp having a lower viscosity contains naturally more low D.P. matter

and is inferior only when this proportion of low D.P. matter is higher than is to be expected for this D.P. level.

DR. LAUER: We tried to replace the clumsy aging process by acid hydrolysis, especially for staple fiber production. We tried mineral acids and acetic acid under all conditions imaginable. You can find conditions under which you obtain an average D.P. of 400 to 500 with uniform polymolecularity and high alpha content. But it was impossible to obtain a rayon thread of acceptable properties, whereas from the same linters or pulp you obtain by the conventional process good fibers.

We also tried to make in the laboratory a viscose rayon of high crystallinity by spinning an alcoholic solution of the trixanthate into an acetone-HCl bath. The fiber was as brittle as a glass fiber and splintered between your fingers. x-ray analysis showed 70% crystallinity.

DR. RAPSON: This applies to both wood pulp and linters. It is not a distinguishing characteristic.

DR. LAUER: Yes, but you still see what the morphology makes. This is also the reason why sulfite pulp is always different from sulfate pulp for rayon.

DR. KRAESSIG: Dr. Lauer, may I ask one question? In this preparation of rayon from cotton linters hydrolyzed or aged to the right D.P. level, did you find any difference in the filtration of the viscoses made from these materials?

DR. LAUER: No, the filtration was fine. We thought when we filtered it well that it must go. We made hundreds of experiments with different acids, different conditions, temperature and everything. It would have been fine. You have an open container. You start with a little acid and get rid—especially for stable fiber, it was important, where you have these ugly presses, in the continuous process and so on, but it didn't work.

MEMBER: Did you make a measure of the D.P. distribution?

DR. LAUER: Yes, it was the same. It was quite regular. What was short was removed in treatment with alkali in the alkalization.

CHAIRMAN HEATH: Dr. Mark has joined us. We are very happy to have you. Something has been said in the discussion previously, about the samples which were sent to you in which you were able to distinguish cotton linters from wood. Do you remember that? They were rayon samples.

DR. HERMAN MARK (Polytechnic Institute of Brooklyn): Yes, I don't quite remember under what conditions it was.

MR. CHARLES: Do you remember that we sent you the samples of tire yarn? This was about 12 years ago, and there were seven samples. Four were from wood pulp and three were from cotton linters. You made x-ray diagrams for them, and you wrote back and told us what the strengths should be of the various yarns within fairly good limits, and you picked out the three from linters, based on less amorphous halo in the diagrams. It was really uncanny the predictions you made. You knew nothing about the samples, and you were able to tell us which were from linters and give us a fairly good idea of the order of strength. I happened to mention this to the audience and when you came in just now they thought you might remember it.

DR. RAPSON: Can we distinguish by x-ray means on the regenerated cellulose, the origin of the pure cellulose?

MR. CHARLES: Anybody could pick it out. With regard to the predictions as to the strengths, that was based on the orientation, but with regard to amorphous halo, anybody with good eyes could look at the diagrams and see the difference. We tried it with many operators and gave them the seven samples, and they picked out the three cotton linters rayons.

That is the background of the question.

DR. MARK: If I may comment on it, as far as my memory sustains me, of course, as you pointed out, the prediction of relative strengths on the basis of relative orientation, degree of orientation, is fairly safe. If one wants to make an absolute statement, of course, one has to have a certain experience of what yarns of that kind, what kind of strengths they may have, and I think combining this general experience with the relative lengths of the segments, that was the first half of it.

I think that the other was essentially something which is similar to the method which was meanwhile developed to a much better extent by P. H. Hermans and what he calls the degree of lateral order.

Since we do not have a blackboard here, I will do it in a type of ghost writing. The diagram of the cellulose, if we imagine we have it on a Geiger counter tracing, would be like this. Of course, there is a lot of intensity in the primary beam, which doesn't mean anything. Then comes a peak, and then comes another peak, small ones. Essentially there is one small peak and then come two big ones.

The statement as to whether or not there was a great deal of laterally poorly ordered material, which would mean that cotton linters have been used which were not completely dissolved, where the structure was not completely destroyed, is essentially made by the relative intensity of the minimum, between 10 and 220, and the maximum.

MR. CHARLES: Linters had none of the halo. It was the pulp samples that had the halo.

DR. MARK: That is correct. I think again that if one has a series of yarns which are made essentially under the same conditions of converting the cellulose into alkalyzed cellulose and then xanthate, and then spinning it, this is a valid distinction.

However, if a cotton linters pulp is processed in one way and the wood pulp is processed in another way, I think this difference will disappear.

Since you indicated to me that those were essentially processed under the same conditions, I felt that this statement would be justified.

DR. RAPSON: Do you still think that it is possible to distinguish cotton from wood pulp by x-ray methods?

DR. MARK: After it has been processed and after it has been spun? Again, if you have four or five samples, four or five yarns, let us say, which have been led through the same process, one based on cotton and the other based on wood pulp, I think one will be able to pick it up in this manner.

On the other hand, if you have a Fortisan type fiber or linen type fiber from one and standard type fiber from the other, then there certainly couldn't be.

DR. RAPSON: To what property of the cellulose do you attribute this difference? That is what we are trying to arrive at here, the fundamental difference between cotton and wood pulp. What is present in the original cellulose that makes this distinction possible or is it something produced during the production of the wood pulp?

DR. MARK: I think the reason why this small difference in the diffraction pattern survives the dissolution and reprecipitation of the cellulose is that cotton is more difficult to dissolve than the corresponding samples of wood pulp; and more of the original structure is carried through the process, if one starts with cotton linters than if one starts with wood pulp.

MEMBER: Is this desirable to have the structure carried through?

DR. MARK: I don't know. I presume that it is true, but again please do not take the statement too seriously. I presume it is still true that if one processes linters in a certain manner to arrive at a high tenacity yarn, that one still has a slight edge over the corresponding process in which any kind of wood pulp is fed. Maybe this is not true any more. It used to be true.

DR. RAPSON: Is it or is it not true? Let us have more opinions.

MR. SUTCLIFFE (Courtaulds (Canada), Ltd.): Let us assume that we seemed to be agreed that you can see this difference

in x-ray patterns. All right, let us take it, as we have at our disposal a range of wood pulps, some of which we know are no good at all for making tire yarns, if it is tire yarns we are talking about, and let us take some which are extremely good. Let us see if these in any way form a graded pattern in this peculiar difference in the x-ray picture, because if they don't, it is a waste of time to look at it from this point of view. It still means something, but from this point of view it is not telling us anything.

Dr. Kraessig: I should like to clarify one point. If I have understood correctly, this difference found 10 years ago was detected by differences in the height of the minimum in the cellulose II diffractogram in the Bragg-angle range 14 to 17°, where cellulose I has its (101) and ($10\bar{1}$) reflection. The diffraction yield at this minimum was higher for the rayon made from cotton linters than for the rayon made from wood pulp, indicating the presence of residual cellulose I. Have I understood correctly?

Mr. Charles: No, it was around the primary beam. This halo that the wood pulps only gave was just adjacent to the primary beam. It was before you get to the (101).

Dr. Kraessig: That would indicate differences in the low angle diffraction which can come from interstices of larger dimensions such as voids in the structure, rather than residues of the original native structure. I base this statement on finds reported by Hermans last year at Syracuse. I should like to comment briefly on my own question. We have recently looked at a large number of rayons. Remarkable differences exist between the older type textile rayons and the new modified rayons in the Bragg-angle region mentioned just a few minutes ago. The new type of tire yarn fibers contains so much so-called cellulose IV that you have in some cases no minimum at all in this region. Therefore it would be very hard to detect the presence of residues of the native structure.

Dr. R. C. Sproul (Philip Morris & Co. Ltd., Inc.): It seems that much of this may start back at the wood pile or the cotton patch, since we have two different processes all the way through. The newly developed or newly publicized cold soda process might be a means toward studying this on a comparative basis because both wood and cotton, I think, will yield to the cold soda process without materially damaging the fiber structures. Some of you fellows who are in this business regularly may find some merit in that suggestion. You may not. Thank you.

Dr. Mark: May I ask a question, Mr. Charles. I don't even know whether those three yarns which have been made from cotton were any better than the others.

Mr. Charles: The cotton linter yarns were 5% better in strength than the wood pulp yarns, but today that might not be true. If we used the same process with the improved wood pulps of today, there would be less difference than that. I am not saying there wouldn't be perhaps still a difference in favor of the cotton linters, but wood pulp has been so much improved that there is a very little difference. In certain properties, for instance, ovendry strengths, of premium wood pulps are better than cotton linters.

Dr. Mark: Your processability?

Mr. Charles: We should go through the same thing again and send yarns made under comparable condition, from cotton linters and from wood pulps because cotton linters have improved too. They have both improved. I think it would be constructive.

Dr. Rapson: I think that experiment is worth repeating.

Dr. Lauer: Those x-ray diagrams made on rayon fibers, the differences may have been caused simply by a difference of spinnability and had nothing to do at all with the cotton and wood pulp problem, because we know that cotton linters are generally more easy to spin and give a stronger thread; so we get a better orientation with a sharp x-ray diagram, and it wouldn't mean anything in connection with wood or cotton.

Dr. Kline (Industrial Rayon): I merely wanted to bring us back to what is supposed to be the object of this research, to uncover the differences between cotton linters and wood dissolving pulp, to aid in the development of a wood pulp grade equivalent to linters.

We have been talking a lot about differences between wood pulp and linters, and I dare say there are a lot of differences. We could spend the rest of our lives to complete studying them, but the objective is to develop a wood pulp equivalent to linters. If that no longer is a problem, then why do it?

I suspect it is not much of a problem.

Chairman Heath: We have been talking about one fairly small area of the rayon industry. I don't think that is true in all products.

Dr. Kline: I have to admit that I am certainly not going to try to say that wood pulp is the equivalent of cotton linters in all respects. I understand there are certain differences still in certain respects, but in many other respects there have been a lot of advances made since ten years ago when the samples were examined, and it seems to me that perhaps the first thing that should be done is to find out if this is a problem, namely, is the problem to develop wood pulp equivalent to cotton linters or the opposite?

Mr. Howard: The chairman could perhaps answer that After all, he is sitting on the fence. He makes both linters and dissolving pulp.

Chairman Heath: It would be my opinion that it is still a problem. In many uses to which wood pulp and linters are both applied, we find differences in the product, in which in many cases, wood pulp is inferior, and in some places wood pulp is superior.

I think while a lot of advance has been made in purification of wood pulp, there are a number of problems that still are left to be solved.

In connection with the suggestion that was made, we would also have to decide which of these rayons make the best tire cord, what criterion would we use for that, would just the strength properties or would we go into the fatigue resistance?

Dr. Kline: Just to add what I think is the obvious, it seems to me that the first step that should be taken is to perhaps repeat 100% the work that was done 10 years ago and see where wood pulp and linters do stack up. Next, Mr. Heath's comments on whether the strengths or fatigue should be studied, it should be both. For that matter, any other physical, chemical, or mechanical characteristics that anyone can think of by which the fibers should be compared, should be looked into.

Mr. Phillip: When we look in the electron microscope for the showing of differences, would this be a place to look for microscopic reflections of the finished material showing the original source?

Dr. Mark: This is perfectly possible because we must remember if one takes a yarn and swells it and then treats it with ultrasonics and disintegrates it, and then spreads it on a screen of the electron microscope, there are very different average lengths and average thicknesses of the fibrils depending on how the yarn was made, and maybe also depending on from what it was made.

Ranby, of course, has done that the first time, and several people did it later. I don't know whether it ever has been done with a set of yarns which were made under simi ar conditions from different sources

Member: I could concede that it would show up in fatigue and strength.

Dr. Kraessig: I expect that the influence of the morphology of the starting material may not be as big in the viscose process as in the acetate process. I would like to mention results of x-ray and infrared analyses of different types of cellulose where we see big differences in the native state, indicating that cellulose from wood pulp has a less perfect lateral order or smaller crystallites than cotton linters, as I

have mentioned in one of my former remarks. After mercerization, however, this difference is almost leveled out.

Another interesting fact which has not been completely proved but may be mentioned here is that, when we analyze by Gjonnes' method the x-ray patterns of heterogeneously mercerized cellulose obtained by steeping we have evidence of the presence of residual cellulose I of high degree of order. The amount of residual cellulose I left in heterogeneously mercerized cellulose is of the order of about 7 to 10% for cotton linters. It may be slightly less in mercerized wood pulp. In general, after mercerization the x-ray diffractograms of both cotton linters and wood pulps are very much alike. I would like to strengthen with this remark what I have said just before, that, in my opinion, existing fine structural differences seem to be leveled out under the swelling conditions prevailing in the viscose process or other processes comprising mercerizing treatments. However, in processes using more hydrophobic and nonswelling conditions, such as the cellulose acetate process, the influence of differences in fine structure will make itself felt, as was shown by the work done by Staudinger and co-workers and some of my own work on the influence of morphology on the course of the substitution reaction.

Mr. Charles: I have a rather facetious comment to make, but it may do some good. We have noticed very much that when you decrease the prices of wood pulp 10% below cotton linters, that it is just as good as cotton linters. But when the price is the same, cotton linters seem to be preferred. That could, of course, be taken to indicate that the differences are small today.

Mr. Wells (Eastman Kodak Co.): I would like to go back to the premise made earlier of the degree of polymerization. The gentleman described two samples which were identical in preparation and history but dissimilar in their behavior. One should remember that differences in D.P., as well as differences in constituent groups on these factions are important. Dr. Carl Malm and his associates have pointed out some years ago that different factions of different viscosities and different degrees of polymerization, when oxidized and mixed in varying ratios made a significant difference in the salt effect in cellulose acetate.

I wonder if his observations might not be pertinent to a study of differences between linters and wood pulp. It may be the differences in substituent groups, between the various factions, might have an application.

Dr. Shiner (Visking Co.): I would like to point out one other difference here between regenerated cellulose prepared from wood pulp and cotton linters. To the best of my knowledge, it is not possible to produce the regenerated cellulose from wood pulp that has the wet strength that one can produce from cotton linters. Maybe there have been some recent developments of which I am not aware. If so, I should like to hear of them.

Dr. Sproul: I wish to make a comment that very significant changes take place in cellulose due to the microorganisms to which cellulose is exposed, and a great deal of the work that we have done in the past may be negated because of that, because we have not, as we go through our laboratory experiments, excluded these organisms that will will affect the cellulose. Abrams has published some information on the loss of strength of cellulose materials, when you would more or less expect the strength not to be lost.

In other words, you wouldn't suspect the loss of strength, and he has attributed that to microorganisms. Possibly Dr. Mark would like to comment on that phase of it. Much of our laboratory work does not exclude microorganism.

Dr. Mark: I really agree with you completely, that at least in our laboratory we do not specifically exclude the possibility of a degradation through microorganisms, although in general I think we have been more afraid and more worried about the question of degradation through oxygen or through acid. I don't want to negate the importance of this warning at all.

Dr. Sproul: I would lead to the point that I think Dr. Mark has confirmed. If we go back and pick up samples that are 12 or 15 years old that have been exposed to light of various kinds, to microorganisms of various kinds, of an indefinite history, unless they have been sealed in tin cans or something of known history, we can spend a lot of time that will be wasted.

Dr. Rapson: I would like to make a general comment about this program and its aims and objects. The question of development of a wood grade pulp equivalent to linters seems to me to not be very well taken. It would imply that one is inferior to the other. This same problem arises in the program of forest biology to develop better fibers.

They wanted to set about embarking on a program to grow better trees, but the problem they were stumped with at the beginning was that nobody could tell them what kind of fibers they wanted 20 or 30 or 50 years from now.

We couldn't agree as to just what characteristics we wanted in fibers. It seems to me that the characteristics of wood pulps for making regenerated cellulose in some respects are better than cotton. In processing, for example, in many respects, wood pulps are better for acetate. When we come to other fine points, such as strength, it is possible that cotton may be better in certain aspects. I doubt if we could agree on the end uses or end properties we want in the final pulp.

It seems to me we have to stick to fundamental differences, which can be discovered in the laboratory, and then let it lie with the laboratories that are making pulp and converting it, to make use of these characteristic differences in the best way they can.

I think it is a false premise that we want to make wood pulp identical with cotton. I think you all know certain disadvantages of cotton that we would not like to build into our wood pulp, I think we should not have the aim to make a wood pulp equivalent to cotton, but to establish clearly for all technologists what are the differences between them and how these can be manipulated for whatever end-use we want to make of each raw material.

Chairman Heath: That was a very good suggestion.

The time is getting late. If there are no more questions or comments, we will call the meeting adjourned.

[The meeting adjourned at 4:30 p.m.]

Pulp Bleaching Conference

of the

Technical Association

of the

Pulp and Paper Industry

Edgewater Beach Hotel

Chicago, Ill.

June 14–16, 1960

ENGINEERING DIVISION

Questions and Answers

Good engineering questions are solicited as well as answers or alternate answers to the published questions. Material should be sent to TAPPI Headquarters, marked for the attention of H. O. Teeple. The items contributed will be forwarded to the Question and Answer Committee for processing. If comments are to be contributed, please refer to the question number.

(1-5/60) *Question:* **What is the measurable loss of stainless steel overlay since the starting of the overlay program?**

(*1.1-5/60*) *Answer:* Due to the variation in service life of different overlay installations, it is impossible to quote the measurable loss of stainless steel overlay since the starting of the program. Some overlays 8 to 9 years old show no measurable loss. Other overlays in service for 18 months show marked preferential attack at the boundary between weld beads which may be as high as 0.050 to 0.100 i.p.j.

(2-5/60) *Question:* **What is maximum per cent of dilution allowed for satisfactory overlay?**

(*2.1-5/60*) *Answer:* We have noted very rapid corrosion in type 310 S.S. overlay with 55 to 60% dilution. We have also seen rapid attack in type 310 S.S. overlay with 30 to 35% dilution. Dilution is not uniform throughout the weld deposit. It should be kept to a minimum. With type 310 S.S. and an $^1/_8$ in. minimum overlay average dilution should be kept to less than 30%.

(3-5/60) *Question:* **In our present procedure we place a stringer bead on the wall of the digester at an angle of 45° with the next bead being placed on top of the one previously placed. My question is why couldn't the bead be placed underneath the first bead which would result in less metal applied and faster application.**

(*3.1-5/60*) *Answer:* Some manual arc overlay has been installed with the succeeding beads placed beneath the previous bead. The service life of this overlay has not been good. It is true that the deposits were thin and less metal was used. However, an overlay should be installed to give maximum service life. Applying the succeeding bead over the previous bead provides a shoulder to hold the molten metal in place till solidified. This tends to prevent mixing with the carbon steel base and limits dilution.

(4-5/60) *Question:* **The type of electrodes and coating allowed for satisfactory overlay?**

R. L. Kirtley,
West Virginia Pulp & Paper Co.,
Luke, Md.

(*4.1-5/60*) *Answer:* Satisfactory overlay has been installed using lime coated type 310 S.S. electrodes. However, there have been some failures using this as well as the titania coated type 310 S.S. electrode. Overlays have been installed recently using an electrode with 28% chromium, 21% nickel, and 2.75% molybdenum in an attempt to increase corrosion resistance and decrease microfissuring. An important factor to consider is the composition of the weld deposit. This will depend on the technique employed and the resulting dilution.

(5-5/60) *Question:* **Has there been any improvements in using metallizing as a means of overlaying? As we understand it the coating is too porous and bonds poorly.**

(*5.1-5/60*) *Answer:* Metallized coatings have not worked well in alkaline digesters. The coatings were porous. They were not bonded to the carbon steel base metal and peeled away. Some metallized coatings have worked in neutral sulfite digester service.

(6-5/60) *Question:* **Is corrosion in dome of kraft digesters caused by condensation of vapors? Could this occur at the time the digester is at full pressure and the contents are several feet from the top? It is assumed that possibly the alkaline liquors do not contact the dome section and that condensed vapor on the dome is acid.**

(*6.1-5/60*) *Answer:* Most kraft mills have not experienced severe corrosion in the domes of digesters. It is very probable that the domes are washed down by condensate and therefore, conditions are not comparable to areas exposed to liquor. The gases and condensed vapors may contain a relatively high oxygen content which would tend to increase corrosion rates.

(7-5/60) *Question:* **Has there been any failures of Lukens or Horton clad lining? If so, from what cause?**

(*7.1-5/60*) *Answer:* There have been several localized failures of stainless clad digesters in kraft service. In one case, failure developed in the welds. It was corrected by rewelding with a different analysis welding rod. Some years ago, several small failures were reported in the cladding. These areas were repaired and the digesters continued in service. The experience with clad digesters has been good.

(8-5/60) *Question:* **What welding rod is recommended for welding to Inconel? We used "132" with good flow characteristics. International Nickel recommended Inconel A. Our welders had difficulty getting this material to flow and give a good nonporous weld. What is the experience of others?**

Harry K. Deits,
Crown Zellerbach Corp.,
Port Townsend, Wash.

(*8.1-5/60*) *Answer:* International Nickel recommends the use of either Inco-Weld A or Inco 142. Inconel electrodes. One panelist reports satisfactory welding of Inconel using the Inco-Weld A rod. It is felt that the welding technique or current setting used is improper where the weld is porous and the weld metal does not flow.

(9-5/60) *Question:* **Is overlay welding of digesters as satisfactory as clad digesters?**

(*9.1-5/60*) *Answer:* The results to date show clad digesters to be superior to overlayed. The overlay has been used primarily to extend the life of carbon steel digesters already in service. However, some overlay has shown no attack after 9 years of service.

(10-5/60) *Question:* **Has overlay welding been in use long enough to prove its efficacy?**

(*10.1-5/60*) *Answer:* Overlay welding in kraft digesters was first installed 10 years ago and is still in place. Some installations are still in perfect condition after 7 to 9 years. There have been failures in overlay. These have been attributed to improper installation procedure.

(11-5/60) *Question:* **If overlay becomes thin or is completely gone, can such an area be overlay welded again?**

(*11.1-5/60*) *Answer:* Where overlay is thin or completely removed, the surface can be re-overlayed provided that the thickness of the shell plate is still adequate for service pressure. Overlay has never been considered as adding additional strength to the shell of the vessel.

(12-5/60) *Question:* **Can a riveted digester be overlay welded and would it be satisfactory?**

(*12.1-5/60*) *Answer:* The general opinion is that riveted digesters should not be overlayed. The welding heat could cause loosening of rivets. Cracks in the weld overlay at the seams could develop. However, portions of some riveted digesters have been overlayed with satisfactory results.

(13-5/60) *Question:* **Is overlay welding as economical as building the digester of a clad material?**

(*13.1-5/60*) *Answer:* It has been reported that a carbon steel digester can be shop overlayed for a total cost which would be less than that of a clad digester. Several shop overlayed digesters are in service. However, due to the probable better life expectancy of a clad digester, based on the number of failures which have developed in overlay, the economics would favor the clad vessel over the overlayed.

(14-5/60) *Question:* **Is automatic overlay welding cheaper than manual overlay welding and is it as satisfactory?**

(*14.1-5/60*) *Answer:* Automatic overlay is cheaper than manual arc overlay if the area involved is large. The break even point in area would depend on the time required to set up the automatic equipment. For small areas the manual arc method is cheaper.

(15-5/60) *Question:* **If overlay is of 310 stainless steel, approximately how much life has been experienced? The life being determined by digester cycles.**

(*15.1-5/60*) *Answer:* Large areas of manual arc overlay made with type 310 stainless lime coated rod, have been in service for 8 years or more. It is estimated that these have gone through over 10,000 digester cycles. The overlay is still in perfect condition.

(16-5/60) *Question:* **Is overlay welding with stainless steel the best and most economical way to extend the life of: (a) old digesters installed and in operation and (b) new digesters to be purchased and installed:**

(*16.1-5/60*) *Answer:* (a) Overlay welding appears to be the best and most economical method for extending the life of an old, installed digester, if the surface and condition of the digester shell is suitable for overlay. Some digester surfaces have been inspected which were not suitable for overlay.

(b) Overlay in new digesters, when properly installed in the shop, could prove to be an economical means of increasing the life. This method should be matched against the excellent performance but higher cost of clad digesters.

(17-5/60) *Question:* **Has any overlay welding been done on digesters cooking a soda cook or a modified soda cook, and if so, what has been the experience?**

FRANK P. MORRISON,
Penobscot Chemical Fibre Co.,
Great Works, Me.

(*17.1-5/60*) *Answer:* Some of the early overlay was installed in digesters using a modified soda cook. It has given excellent service. More recent overlay has given varying results.

(18-5/60) *Question:* **How extensive has overlay welding been used, i.e., how many actual digesters have been overlay welded?**

(*18.1-5/60*) *Answer:* One estimate gives a figure of 260 digesters with overlay installed. The area covered ranges from several square feet to the entire inside surface.

(19-5/60) *Question:* **Has overlay welding been practiced in all the principal pulp producing regions in North America?**

(*19.1-5/60*) *Answer:* Yes, overlay has been installed in all the kraft producing regions in this country.

(20-5/60) *Question:* **How many years since the first digester was overlay welded in North America?**

(*20.1-5/60*) *Answer:* The first small overlay areas were installed in January, 1950. These areas were still in excellent condition when the shells were completely overlayed a short time ago.

(21-5/60) *Question:* **Has there been any evidence that the results with overlay welding have improved as the techniques and the means of applying the weld have improved?**

(*21.1-5/60*) *Answer:* The early overlay is still in excellent condition. Some of the overlay installed 4 to 5 years ago, with speed up application and very thin deposits failed rapidly. It is believed that technique has been improved and that newer installations will give satisfactory service.

(22-5/60) *Question:* **Is the skill and the care used in applying the weld an extremely critical factor in theperformance of the overlay?**

(*22.1-5/60*) *Answer:* Yes, skill and care are of critical importance in securing good service life. Deposits should have sufficient thickness to provide the necessary corrosion resistance.

TAPPI STANDARDS

Testing Methods, Specifications, and Recommended Practices

Starch in Paper

Revision of TAPPI Standard T 419 m-48, Reclassified as a Tentative Standard

(THIS STANDARD IS UNDER THE JURISDICTION OF THE CHEMICAL METHODS COMMITTEE)

THIS standard describes procedures for the qualitative and the quantitative determination of starch in paper.

QUALITATIVE

Reagent

Iodine Solution, 0.001 *N* I_2. Make a 0.01 *N* stock solution of iodine by dissolving 0.13 g. I_2 in a solution of 2.6 g. of potassium iodide in 5 ml. of water and diluting to 100 ml. Dilute a portion of this to a pale yellow color (about 0.001 *N*) each time a test for starch is made.

Procedure

A positive result obtained by the following procedure is conclusive evidence of the presence of starch in paper: Boil about 0.5 g. of the paper specimen for several minutes with 10 ml. of water. Filter, cool the filtrate, and add 1 drop of the approximately 0.001 *N* I_2 solution. A blue coloration indicates starch. A faint violet coloration should be disregarded, as nonstarch constituents of paper sometimes give such a reaction.

QUANTITATIVE

This method is a colorimetric one (*1*). The results are not seriously affected by other polysaccharides that are present in ordinary papermaking pulps. After extraction with water and hydrochloric acid, the starch is determined by measuring the absorbance of the starch-iodine complex of 580 to 610 μ. A limitation in the accuracy of the method is some difference in color produced with different types of starch. This has been investigated to some extent (*2*).

Apparatus

1. *Disintegrator,* for disintegrating the specimen in water. A domestic high-speed electric mixer is most suitable for this purpose. Any other means for preparing the specimens, e.g., glass beads and bottle may be used.

2. *Fritted glass filters,* coarse, about 50 ml. or larger to allow rapid filtration of the hydrochloric acid solutions during the extraction of the starch from the paper.

3. *Centrifuge,* preferably with a capacity of over 50 ml.

4. *Spectrophotometer,* for absorption measurements at 580 to 610 μ.

Note: A filter comparator may be used, especially for a sample in which the type of starch used is unknown. In any case, use the same instrument and conditions for the calibration curve as for the specimen.

5. *Suction flask,* 500 ml. or larger, with its suction line provided with a three-way cock and connections so that when its suction is cut, off a slight back pressure can be applied to the flask by blowing through the tube attached to the three-way cock.

6. *Other Equipment,* 50, 100, and 500-ml. volumetric flasks, 25, and 2.5-ml. pipets and a boiling water or steam bath.

Reagents

A. *Hydrochloric acid,* concd. HCl, also solutions diluted 1+1, 1+9 and 1+19.*

B. *Potassium iodide-iodine reagent,* 7.5 g. KI and 5 g. I_2 per liter. Dissolve 5 g. I_2 in a solution of 7.5 g. of KI in 10 ml. of water and dilute to 1 l.

C. *Cotton linters.*

Test Specimen

From a representative sample of the paper, weigh to the nearest 5 mg., a 1-g. specimen for the starch determination consisting of small strips. At the same time, unless the moisture content is known to within one or two per cent weigh another 1 or 2-g. specimen for a moisture determination according to TAPPI Standard T 412 or T 484 m.

Note: Do not dry-grind the paper since papers containing mineral filler may lose some of the filler and may also lose starch.

Procedure

Transfer the specimen, cut into small pieces, to the disintegrator, disintegrate in a small quantity (60 ± 20 ml.) of distilled water, transfer quantitatively to a 250-ml. beaker, using enough rinsing water to make the specimen up to 100 ml. Heat on the bath to just below the boiling point, for 15 min.

Transfer the contents of the beaker to the suction crucible on the suction flask. Drain and wash away the residue with 10 to 12 ml. of hot water. Turn the three-way cock in the suction line so as to cut off the suction and connect the flask with the tube. Blow gently in the tube so as to create a slight back pressure in the flask, then turn the cock to seal it. Add 25 ml.

* This new nomenclature is suggested instead of 1:9, etc., because many read 1:9 to mean 1 HCl to 9 of the mixture.

Table I. Dilution Procedure for Preparing a Calibration Curve

Starch concentration, mg./l.	*Total volume, ml.*	*0.2 g./l starch solution, ml.*	*Water,[a] ml.*	*KI solution,[b] ml.*
10	100	5	0	5
20	100	10	5	5
30	100	15	10	5
40	100	20	15	5
50	100	25	20	5
Dilute to the mark in a volumetric flask with 1+1 HCl.				

[a] Graduated cylinder is sufficiently accurate
[b] Add this solution from a pipet or buret

of 1+1 HCl to the filter crucible, allow to stand for 175 to 180 sec., and apply the suction. Re-establish the back pressure in the flask and repeat the 2-min. extraction with 25 ml. of 1 + 1 HCl. Drain and re-establish the back pressure, add 25 ml. of conc. HCl and allow to stand for 19 to 20 sec. Reapply the suction and twirl the flask so as to mix the conc. HCl in the filtrate. Wash the residue with about 200 ml. of hot water and test for complete removal of the starch by adding a drop or two of the dilute iodine solution. Even a trace of residual starch will cause the appearance of a blue color.

Note: The fritted glass filters may be cleaned by passing 5 *N* NaOH through the filter and washing at once with hot water.

Transfer the starch solution to a 500-ml. volumetric flask, cool to room temperature, and dilute to the mark with water. Mix thoroughly and, if the solution is turbid because of fillers or other extraneous material, centrifuge approximately 50 ml. for 10 min.

Pipet 25 ml. of the clear supernatant liquid into a 50-ml. volumetric flask, pipet 2.5 ml. of the KI-I_2 reagent into the flask, dilute to the mark with water and mix thoroughly. Measure the absorbance at 580 μ against a reference solution prepared by diluting 25 ml. of 1+9 HCl and 2.5 ml. of the KI-I_2 reagent to 50 ml. in a volumetric flask. Read the starch concentration from a calibration curve and calculate the starch content as a percentage of the ovendry paper.

Note: As many centrifuges do not have a capacity of 50 ml., a different dilution procedure may be necessary. A convenient procedure is to add an equal volume of diluted KI-I_2 solution (10 ml. reagent B diluted to 100 ml. in a volumetric flask) containing 0.75 g. and 0.5 g. I_2 per liter, to the available centrifuged starch solution and measure the absorbance against the reference solution prepared in the same way.

Calibration Curve

If possible, use the same starch that was added to the paper for preparing the calibration curve. Otherwise, use a composite mixture of three or four common types of starches. Weigh 0.1 g. starch corrected for moisture and ash into a 250-ml. beaker, add 100 ml. distilled water and heat for 15 min. just below the boiling point. Add 1.0 g. cotton linters to the solution and heat 15 min. longer. Decant with suction through the coarse fritted glass filter, wash once with hot water and refilter the water through the mat.

Proceed with the HCl and extraction treatments exactly as described for the paper specimen, diluting the filtrate to 500 ml. in a volumetric flask. Centrifuge a portion of this starch solution for 10 min. and remove aliquots to prepare the calibration curve. Keep all the concentrations and the period between forming the starch-iodine complex and measuring its absorbance the same as used for the specimen. A suggested dilution schedule is given in Table I.

Note: The ash content of starch can usually be neglected. Acid-modified starches, oxidized starches and starches containing borax may contain 1 or 2% ash.

Report

Report the amount of starch as a percentage of the moisture-free paper to the nearest 0.1.

Note: In accordance with experimental findings (*2*), the percentage of starch added to wood pulp papers is usually less than that found by this method, the relationship being approximately: % actual starch = (% starch found × 1.2 − 0.3). State prominently in the report if this correction is made.

Precision

The standard deviation from a limited number of tests with different starches, using the added starch for calibrating, was about 0.06% starch.

ADDITIONAL INFORMATION*

1. Although a limited number of experiments indicate that centrifuging has no measurable effect on the results, it is suggested that data be obtained with and without centrifuging until this is clearly established.
2. This revision is comprehensive and substitutes a colorimetric starch-iodine procedure for the previous enzymatic conversion of the starch to glucose and the determination of the latter with Fehling's solution.
3. Related Method: ASTM D 591-42.

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* Since this method was approved, it has been suggested by the Verein der Zellstoff und Papier Chemiker und Ingenieure that the chemical composition of the starches used and their subsequent oxidation, have such a marked effect on the color of the starch-iodine complex as to make the accuracy of this method questionable when unknown samples are analyzed. The "draferman" method, described by Freezer in "*Die Stärke*" 10:38 (1958) is recommended instead. This will receive attention for a subsequent revision.

Flow Measuring Methods

TAPPI Data Sheet No. 71E

(THIS DATA SHEET IS UNDER THE JURISDICTION OF THE CHEMICAL ENGINEERING COMMITTEE)

WEIR FLOWS

Flow, Gallons per Minute

Head, in.	*90° V-notch*	*Rectangular, width*					*Each additional foot*
		6 in.	*9 in.*	*1 ft.*	*1 1/2 ft.*	*2 ft.*	
3/8	..	4.04	6.08	8.2	12.3	16.4	8.2
1/2	..	6.25	9.55	12.4	18.9	25.3	12.9
5/8	..	8.70	13.03	17.1	26.1	35.0	17.9
3/4	..	11.45	17.03	22.4	34.1	45.7	23.3
7/8	..	14.20	21.53	28.4	42.9	57.4	29.0
1	..	17.30	26.25	34.9	52.9	70.9	36.0
1 1/8	..	20.60	31.5	41.8	63.4	84.9	43.1
1 1/4	4.22	24.15	37.0	49.1	74.4	99.7	50.6
1 3/8	5.34	27.75	42.7	56.7	85.9	115.1	58.4
1 1/2	6.50	31.7	48.6	64.6	97.9	131.1	66.5
1 5/8	7.98	35.7	54.7	72.7	110.2	147.6	74.9
1 3/4	9.50	39.7	61.0	81.0	122.8	164.6	83.6
1 7/8	11.2	43.7	67.5	89.5	135.8	182.1	92.6
2	13.2	47.8	74.2	98.2	149.1	200.0	101.8
2 1/8	15.6	52.0	81.0	107.1	162.8	218.4	111.3
2 1/4	18.1	56.3	87.9	116.3	176.9	237.4	121.1
2 3/8	20.7	60.7	94.9	125.8	191.4	257.0	131.2
2 1/2	23.6	65.2	102.0	135.6	206.4	277.2	141.6
2 5/8	26.6	69.8	109.2	145.7	221.9	298.0	152.3
2 3/4	29.8	74.5	116.5	156.1	237.8	319.5	163.4
2 7/8	33.2	79.3	123.9	166.9	254.4	341.8	174.9
3	36.8	84.2	131.4	178	272	365	187
3 1/8	40.7	89.0	139.0	189	289	388	199
3 1/4	44.9	94.1	146.8	200	306	411	211
3 3/8	49.3	99.2	154.8	211	323	434	223
3 1/2	54.1	104.4	163.0	222	340	457	235
3 5/8	59.0	109.6	171.4	233	357	480	248
3 3/4	64.0	114.9	180.0	244	375	505	261
3 7/8	69.5	120.2	188.8	256	393	530	274
4	75	125.5	197.8	268	412	556	288
4 1/8	81	130.8	207	280	431	582	302
4 1/4	87	136.1	216	292	450	608	316
4 3/8	93	141.4	225	304	469	634	330
4 1/2	100	146.7	234	317	489	661	344
4 5/8	107	152.0	243	330	509	688	358
4 3/4	114	157.3	252	343	529	715	372
4 7/8	122	162.6	261	356	550	743	387
5	130	167.9	270	369	570	771	402
5 1/8	138	173.3	279	382	591	799	417
5 1/4	147	178.7	288	395	611	827	432
5 3/8	156	184.1	297	408	632	856	448
5 1/2	165	189.5	306	421	653	885	464
5 5/8	174	194.9	315	434	674	914	480
5 3/4	183	200.3	324	448	696	944	496
5 7/8	194	205.7	333	462	718	974	512
6	204	..	..	476	740	1004	528
6 1/8	215	..	..	490	763	1035	545
6 1/4	226	..	..	504	785	1066	562
6 3/8	237	..	..	518	808	1097	579
6 1/2	249	..	..	532	830	1128	596
6 5/8	261	..	..	546	853	1159	613
6 3/4	273	..	..	560	875	1190	630
6 7/8	286	..	..	574	898	1221	647
7	299	..	..	588	920	1252	664
7 1/8	312	..	..	603	944	1285	682
7 1/4	325	..	..	618	968	1318	700
7 3/8	339	..	..	633	992	1351	718
7 1/2	354	..	..	648	1016	1384	736
7 5/8	369	..	..	663	1041	1418	755
7 3/4	384	..	..	678	1065	1452	774
7 7/8	400	..	..	693	1090	1486	793
8	416	..	..	708	1114	1520	812
8 1/8	432	..	..	723	1139	1554	831
8 1/4	448	..	..	738	1164	1589	851
8 3/8	465	..	..	753	1189	1624	871
8 1/2	482	..	..	768	1214	1659	891
8 5/8	500	..	..	783	1239	1694	911
8 3/4	518	..	..	798	1264	1729	931
8 7/8	537	..	..	813	1289	1764	951

Issued December, 1940. Revised Feb. 1960.

ROUTINE CONTROL METHODS

RC-277. Dirt in Pulp—Measured by Transmitted Light

Object. To determine the amount of dirt specks per gram in a given pulp sample as measured by transmitted light.

Apparatus. (1) Pulp disintegrator; (2) Buchner funnel for 15-cm. filter paper, 2000-ml. suction flask, and filter papers (15 cm. and 18.5 cm.); (3) hydraulic press; (4) blotting paper; (5) viewing box.

Procedure. Each dirt handsheet is prepared from a pulp suspension of 500 ml. at 3% consistency to give a handsheet approximately 1.5 g. in weight. Two to four handsheets are prepared for each sample.

These sheets are formed in a Buchner funnel, being sure that the funnel is level before pouring in the pulp suspension, to insure that the sheet is of uniform thickness. The formed handsheet and filter paper is blown onto an 18.5-cm. filter paper. This gives a sample consisting of an 18.5-cm. filter paper, the handsheet, and a 15-cm. filter paper. This "sandwich" is placed on two standard blotters and covered with two more. These blotters and sheets may be stacked to any height.

The stack of blotters, filter papers, and handsheets are pressed in a hydraulic press for 1 min. at 180 p.s.i.g. on the sheet. The filter paper and sheets are dried, placed in a desiccator, and the handsheet weighted after it has cooled for 5 min. in the desiccator.

The sheets are placed, one at a time over the viewing glass and every speck 0.04 sq. mm. area or larger is counted using transmitted light. Specks are circled and the sheet is turned over to insure that all specks are counted.

Report. The average of the dirt handsheets for each pulp sample are reported as the number of dirt specks per gram of pulp, expressing it to the nearest 0.1.

This is a Routine Control Method and should not be considered as a Standard in any way. Corrections may be made before loose-leaf publication. Comments will be welcome and should be sent to A. J. Winchester, TAPPI, 360 Lexington Ave., New York 17, N. Y.

RC-278. Use of the Vanceometer

Object. The purpose of this method is to detail the use of the Vanceometer and its calibration so that the optimum accuracy and precision can be attained. This instrument has found wide application, especially in the testing of paperboard as a means of estimating the oil resistance characteristics.

Apparatus. The sample holder is a ramp of black glass. This ramp also serves as the 100% standard. It is hinged to the body of the instrument so that it can be swung up to cover the sample opening of the light measuring chamber.

The other part of the instrument is a hollow polished cylinder 4 in. in diameter and 4 in. long, weighing $8^1/_3$ lb., which serves to apply the oil to the specimen.

A Vanceometer.

The test fluid is silicone (200 cs. viscosity is preferred, but not necessarily). This fluid shows very little change in viscosity with temperature.

Discussion. This instrument is based on a measure of the glass. For this measurement, the light from a standard projection lamp through a collimating lens is incident on the sample opening of the instrument at approximately 70° and is measured by a photocell which is connected to a galvanometer. An iris diaphragm is placed at the photo tube for adjustment of the 100% reading. The entire measurement chamber is coated in black and is made ressonably light-tight. Light from the source enters the chamber through a small aperture.

The Vanceometer, like any other instrument measuring gloss, must be calibrated at more than one point. It is not sufficient to set the black glass ramp in place and adjust the diaphragm to give a reading of 100%. The manufacturer will provide tiles of intermediate gloss readings to calibrate the instrument. To make the adjustment, the cover of the light and measurement chambers must be removed and the position of the light housing moved until the instrument is reading correctly at at least two, and preferably three, different gloss readings.

Procedure. Prior to making a series of readings put the black glass ramp in position over the sample opening and adjust the iris diaphragm until the meter reads 100%. If it is impossible to obtain 100% when the diaphragm is wide open, the bulb must be replaced. After replacement of the bulb the instrument must be calibrated.

The sample of paperboard is cut to fit on the glass ramp (approximately 5 by 12). Place the specimen on the ramp under the holder clips if these are provided. The machine direction of the specimen should be parallel to the beam of light, i.e., parallel to the long dimension of the specimen.

Place the roller on the sample. With an eyedropper, drop 1 ml. of the test fluid on the roller so that when the roller turns and the point of application reaches the sample, it is directly in front of the sample opening of the instrument. With some practice this point can be readily determined and repeated regularly. (It has been found that an eyedropper with the proper bulb size will deliver the amount of fluid required with sufficient precision.)

Report. When the fluid is applied, immediately start the stopwatch or timer. (On *some* instruments this is done automatically.) Immediately raise the ramp to the vertical position so that the oil smear covers the sample opening. Record the time for gloss to reach 60%.

This time is considered to be the Vanceometer reading.

This is a Routine Control Method and should not be considered as a Standard in any way. Corrections may be made before loose-leaf publication. Comments will be welcome and should be sent to A. J. Winchester, TAPPI, 360 Lexington Ave., New York 17, N. Y.

* This method is based on the work of Edwards and Curran.

11th Testing Conference

of the

Technical Association of the

Pulp and Paper Industry

Pantlind Hotel

Grand Rapids, Mich.

Sept. 27–29, 1960

LOCAL SECTION ACTIVITIES

Meeting Calendar

May, 1960

27 Delaware Valley Section, Beloit Eastern, Downingtown, Pa., tour and outing.
27 Lake Erie Section, Annual Outing and Ladies' Night.

June, 1960

3–4 New England Section, Chatham Bars Inn., Chatham, Mass., Spring Meeting.
10–11 Empire State Section, Whiteface Inn, Whiteface, N. Y., Annual Meeting
17–18 Maine-New Hampshire Section, Mountain View House, Whitefield, N. H., Annual Meeting.
21 Kalamazoo Valley Section, Annual Golf Outing, Gull Lake Country Club.

September, 1960

12 Eastern District, New England Section, Armand's Beacon Terrace, Framingham, Mass.
15 St. Louis Section, Le Chateau Restaurant, 10405 Clayton Rd., St. Louis County, Mo., "Paper Coatings Based on Cellulose Derivatives and Parlon Film Formers on Paper."
21 Pacific Section, Salem, Ore., "Modernization."

October, 1960

7–8 New England Section, joint meeting with Connecticut Valley PIMA, Schine Inn, Chicopee, Mass.

November, 1960

14 Eastern District, New England Section, Armand's Beacon Terrace, Framingham, Mass.
17 St. Louis Section, Le Chateau Restaurant, 10405 Clayton Rd., St. Louis County, Mo., "Recent Advances in the Packaging Field," by C. P. Olstad, Crown Zellerbach Corp.

December, 1960

5 New England Section, Storrowton Tavern, West Springfield, Mass.

January, 1961

9 Eastern District, New England Section, Armand's Beacon Terrace, Framingham, Mass.

March, 1961

13 Eastern District, New England Section, Armand's Beacon Terrace, Framingham, Mass.

April, 1961

10 New England Section, Storrowton Tavern, West Springfield, Mass., Management Night.

June, 1961

8–10 Joint Meeting, New England Section and Maine-New Hampshire Section, Wentworth-by-the-Sea, N. H.

Delaware Valley

The Delaware Valley Section of TAPPI held its monthly meeting on Jan. 21, 1960, at the Engineers' Club in Philadelphia. Speaker at this meeting was Gilbert A. Shedd of International Business Machines who spoke on "Data Processing in the Paper Industry." Mr. Shedd, with IBM for 32 years, has spent his last eight years serving the manufacturing industries as a specialist in applying systems and procedures to various manufacturing processes. The text of Mr. Shedd's talk follows.

THOMAS P. CZEPIEL, *Secretary*

Data Processing in the Paper Industry

Gilbert A. Shedd

I FIRST want to state something that I am sure you will be aware of before I have gone very far, that is that my talk will be based on the use of IBM data processing equipment in the paper industry. I hope you will pardon me because I have spent my complete business life of 32 years with IBM. The use of this equipment in your industry has been longstanding and has extended through practically all areas of cost and accounting records. Not too much has been done in the engineering and research areas until recent years. This has been due to two causes in my opinion. The major use of punched card equipment in general industry has always been in the accounting and statistical areas. We in the in-

GILBERT A. SHEDD, International Business Machines, Inc., Endicott, N. Y.

Gilbert A. Shedd of International Business Machines addresses the January meeting of the Delaware Valley Section of Tappi

dustry often admit to ourselves that our customers develop the uses of our equipment and then educate us so that we can expand the business. Since we have worked with the accounting departments, expansion has taken place there. The second factor is that only in recent years has the new high-speed computing equipment been developed which has opened the field of engineering and operations research to the mathematical potential of these electronic "brains." It is my belief that the coming years will see a growth in the use of this equipment in the engineering and research areas as experience is gained and our customers teach us how they should be used.

As I stated before the use of data processing in the accounting areas has been widespread in the paper industry and has covered practically all types of accounting. The work performed has taken on the form of that in all types of general industry. This is probably due partially to our experience in general industry and the natural tendency to suggest uses and operations that we have had experience with and that are familiar to us. In my opinion, which has been developed by a study in the past year, it is also due to the fact that general accounting problems in the paper industry are practically the same as those in general industry. In this area I am including order processing, billing, sales accounting, inventory control, payroll, cost accounting, and all other phases of general accounting work. I may be completely wrong about this due to a lack of appreciation for the basic problems but I have been unable to uncover any peculiar or specific problems through discussions with people in the industry. If there is something of which you are aware I would certainly appreciate hearing of it since we want to serve you in the best way possible. I claim no great wisdom regarding your industry.

One of the most common uses of punched cards for years has been in the area of sales analysis. In the paper industry this is usually built on both the analysis of orders received and on shipments made. Orders received must be analyzed and summarized by grade, basis weight, finish, size, etc., as well as by required delivery dates in order to schedule the production on the machines. This, of course, can be done mechanically by punching a card for each item ordered and mechanically producing the required summarizations. In the case of shipments these same analyses, by product, form the basic data for computing cost of sales and inventory accounting. In the larger companies with many plants the scheduling of production includes the consideration of the area to which shipment is to be made so that minimum transportation costs are involved. The new electronic computers have opened up new approaches to this problem which are now being studied.

The result desired is to secure minimum cost with best service by balancing the least transportation cost with the most efficient and most economical production available. To do this the cost of production on each available machine must be considered by type of paper, the production capacity must be matched with required delivery schedules, number of setups and changes must be evaluated, and the need to maintain continuous production must not be forgotten. New computers and linear programming techniques have opened a mathematical approach to this problem. Better and better results will be secured as we gain experience and improve the approach.

Many companies have also used punched card equipment to prepare invoices to customers. This operation is particularly economical where standard grades and specifications of paper are sold at standard prices or relatively large contracts are taken. A supply of cards which we term prepunched, can then be set up for each item or contract carrying not only the description of the item but also the price. The price is checked once when the supply of cards is made, all desired codes are applied and checked once and accuracy is assured on all invoices and records without checking each individual item on each bill. Cards are selected for items shipped and only the quantity needs to be entered and checked individually. Computers and calculating punches are available in all sizes and capacities to extend these cards and invoices can be printed at speeds from 50 to 600 lines, not characters, per minute depending on the requirements. The cards which prepare the invoice are then available, of course, for a sales analysis by industry customer, territory or salesman, state, and whatever classifications are desired. These data are being used more and more as time goes on because of the increased importance of sales forecasting. The new computers will, in my opinion, make this field much more important as new statistical techniques are developed and experience is gained in the relationship of available statistical figures from government bureaus or trade associations to individual company sales are established. Forecasting will become more and more of a science and more accurate and therefore be more widely and effectively used.

Where invoicing is done on this equipment we have the ability to automatically produce a total card for each bill. This total card can carry customer and salesman identification and many companies use it for accounts receivable and salesman commission records. This makes the posting of these records automatic and mechanical since the total cards are the record and are themselves subject to mechanical processing. In the area of accounts receivable I would like to take time to comment in a little more detail. There are two types of accounts receivable statements submitted to customers. One is the balance forward and the other the open item. The balance forward system has been the more common due to ease of preparation. As the name states it starts each period with a balance owing and adds new charges and subtracts payments to secure a new balance due. This statement can be produced as a copy of the current period posting to the ledger record. This is easy but gives no explanation of the balance carried forward. The open item statement shows each item still unpaid instead of the balance forward. Under manual methods this requires preparing the statement as a separate operation by listing unpaid items in detail. This is time consuming and costly. The punched card makes this more complete and informative statement practical. Cards punched from invoices are filed mechanically by customer. As payments are received the paid items are pulled. Open unpaid items are represented by cards remaining in file. These cards are mechanically listed at machine speeds to prepare the complete open item statement. No question remains as to what makes up the amount due and no credit letters are received requesting detail explanation of the balance forward. With the now popular voucher system of accounts payable, which eliminates the accounts payable ledger and shows only unpaid items in file, I believe the open item accounts receivable system will become more popular since it provides a record comparable to the customer's record and makes reconciliation easier. This method also makes it easy to age the accounts receivable and have true credit management.

Inventory records showing quantities on hand for both salable and supply items are also maintained on data processing equipment by many companies. These records are often kept in combination with other operations. Entries to inventory are always a second entry of data used in some other way. Where invoicing is done by data processing, the card that printed the invoice line can be used to enter the stock withdrawal from inventory. Where a maintenance or supply item is requisitioned from inventory the same item is charged to the expense record. Production records are the basis for charges into inventory as is material purchased and paid for in accounts payable. Accounting by means of data processing takes advantage of this double accounting entry. In addition to this it permits inventory management. The large number of items in the average inventory practically prohibits detail continuous study of each item. The

principle of management by exception must be used with the machine detecting the exception by means of established rules. Mechanical processing permits breaking down the inventory into classifications by type of material, end use, responsibility, storage requirements, unit value, liability of obsolesence, and other factors affecting management decision. Summary reports can then be prepared showing inventory value and use, or turnover, by these small groups to reveal any out-of-balance conditions. Possibly unstable price conditions in a material may affect desirable inventory or storage requirements may cause new arrangements of warehouses. Another important factor is always age. Inventory value classified by date of last use can be the means of recovering capital and reducing storage expense and loss by obsolesence. Rules can be established by classification which will be applied by the machine to each item and questionable situations can be reported.

We have customers now using and planning to use a new machine, the IBM Ramac, to combine the billing and inventory control operations. This machine, to those of you that have not had an opportunity to get familiar with it, stores 5 or 10 million characters on a file of 50 disks in the form of magnetic bits. It has true random access in that any information is available in about half a second by a specific address. By storing customer names and addresses, product descriptions and prices, inventory by warehouses, and various salesmen and territory sales, a complete billing inventory posting and sales analysis can be done in one on line operation. The machine supplies all prices, extends the quantity shipped and prints the invoice. At the same time it will check credit, check for availability of inventory and post the inventory record, enter sales on the salesman commission record, and post sales by product for sales and cost records. We feel this machine is the first of a new approach to data processing since the in line approach permits immediate editing of data and maintaining up-to-the-minute records on all desired data. Current reports are quickly prepared. The machine also has an inquiry feature which permits securing the up-to-the-minute inventory balance, shipments of a product, and like data at once.

In the past few years more and more companies have turned to mechanical systems of payroll accounting. This has of course been brought about by the many tax systems and reports now required. The situation is more difficult depending on the number of states and cities included in the payroll but is difficult enough when you operate in one location. Added to this are the problems of pension and retirement plans and numerous deductions. We have customers using all types of data-processing equipment preparing complete payrolls and tax reports. Programs have been developed and checked out with the states and federal governments and approved by them. Most tax forms have already been designed by the various governments to be prepared on data processing equipment. As you undoubtedly know the Social Security and Federal Income Tax Departments use this equipment for their records.

With the preparation of payroll goes the normal cost accounting work. This, too, is done on data processing. Labor and material costs are distributed to the proper cost records by account, work order, or appropriation as required. With this goes budgetary control for operations. The new expanding system of flexible budgets is particularly adaptable to mechanical processing due to the amount of calculating required. Budget amounts, over and under totals, and per cent of efficiency or variation can be automatically computed from base production, shipment, or sales figures. The budget reports are then prepared on the machines ready for submission.

Many companies use data processing systems for handling their accounts payable records. This is a relatively simple operation. Vendor invoices are recorded on cards with the accounting distribution desired. A second set of cards is automatically prepared. One set of cards is filed by due date and used for payment of the bills. This set of cards is used to prepare reports of amount due by date to establish cash requirements. On the due date the cards are selected and used to print remittance statements and checks. The distribution set of cards are used to prepare accounting reports and expense journals.

Property records are becoming a more important part of business each day as more and more equipment is required to operate a modern business. If these records are established on data processing cards, property lists, depreciation charges, and investment records can be mechanically prepared on automatic machines classified and summarized in as much detail as desired. Computation of proper depreciation charges becomes more important as they become a larger part of costs. Systems based on production require more records and more computation. New tax laws require continual review of property to select the system with least cost. The distribution of these charges must also be more accurate if costs are to be accurate. These problems have been responsible for causing many companies to set up a unit card for each property item containing the original value, purchase date, expected life depreciation rate, location, and other similar data. If these cards are data processing records then all desired analysis and reports can be secured from them by machine methods.

I believe you will agree with me that data processing equipment is being used in practically all areas of accounting records. As I stated before these uses are basically the same in all industries and variations are due to different requirements in individual companies as much as to the different industries.

There are a few records that take a slightly different emphasis in paper manufacturing than in most industries, although they are basically the same.

The maintenance and repair of equipment is a major item of cost and continuous service of equipment is vital since production is machine production. This means a complete and detailed record of machine operation, performance, and maintenance hours and cost is required. These records are kept on data processing equipment to reduce the need for detail manual posting to machine record cards. Individual records of maintenance time, material used, and detail section of the machine repaired are made on punched cards. A record is also made of the maintenance man making the repair. Production by machine is punched on cards for both regular production records and for maintenance purposes. By combining the maintenance records cards and production cards a complete report by paper machine and machine section can be easily prepared. This will not only detail performance and costs but reveal areas of excessive repairs and downtime in proportion to production and permit prompt action to correct trouble areas. One company that I know of has used this type of record in a further unusual way. They prepare a daily sheet listing repairs made by each maintenance man showing hours and material used by type of repair. This is posted in the plant for all to see. The pride of each man is appealed to in that he does not want a poor job displayed for other maintenance men to see. This is another way to reduce maintenance costs.

A problem which is nearly distinctive to the paper manufacturing business is the "trim problem." This has received some publicity over the past year and several articles have been published in trade magazines suggesting a mathematical solution using computers of different capacities. There is no question but that a slight improvement in efficiency here can result in a large cost saving. The reward for success will be great. I am sorry I know of no company with the solution completely worked out, although many are working on it and have tried solutions. This does not mean it will not be worked out but only that work remains to be done. The problem has been approached by means of linear programming and solu-

tions have been secured. We find, however, that in individual companies, working with actual orders, the normal situation is a wide variety of requirements on a few orders to be produced to meet short delivery schedules and no inventory production. The restrictions permit little grouping of like specifications to be trimmed and scheduled at the same time. If you do not have a variety of orders to be trimmed from the same specifications the selection to be made is limited and fairly obvious. We hope in the future to expand the selection or to be able to develop a machine approach to more phases of the problem. This will permit computers to enter in area where large savings can be realized. Here, in this type of problem, we are particularly eager to receive suggestions from people in the industry. I believe that only you people who really understand the problem can define it and suggest the ultimate approach to the best solution.

Many paper manufacturing companies of today have their own forests. Management of these forests has become a science in itself. Development of this science has called for statistical records of experience and results under the various conditions. Several paper companies have used data processing for these statistics. The foresters in charge have set up the factors they wish recorded and the correlations of data desired. The test plots and trees are selected by the foresters also. Not being an expert in the field I will not attempt to explain the detailed approach but merely state that once the desired data are in machine processable form all types of statistical studies and correlations are available. Large volumes of statistical results are printed and studied by the management and operating personnel.

It might be well to mention methods of recording data for this purpose at this time. Mark-sensing is used to record the desired data in some cases. This means that the person making the original record does this by making a pencil mark in the position on the card assigned to record the particular fact. A mark-sensing punch will read the pencil mark and automatically punch a hole in the card. This eliminates the key punching operation. The pencil mark is made with a lead containing a high per cent of graphite which will conduct electricity. The resulting current punches the hole. Another approach to this same automatic punching has been the Port-A-Punch. This is based on cards having each hole position scored. The person making the original recording uses a stylus to punch out the desired holes.

The settlement for wood purchased has also been mechanized by some companies. This operation may be based on weight but where it is based on measuring the wood it involves considerable calculation. In a specific company that I know of, the height of wood on the freight cars is measured in eight places, the length is known and allowances are entered for holes in the pile, branches, and soft wood. These data are punched on cards. The calculator computes average height and from this with length and various allowances it computes net cords. The amount due less allowances for hauling and cutting is then computed and the check to the grower is prepared. This complete machine operation is further extended by recording the freight car numbers and using the cards to audit the freight bills.

The capacity of the new computers and the increasing interest in the use of mathematics in the field of engineering and operations research is rapidly expanding the use of equipment in these areas. Some companies are now working in the areas of mill design and machine design. Studies are also being carried on in quality control and the operating processes of both pulp and paper. These studies are being made by individual companies and naturally specific data on results are not available. I firmly believe, however, that this will be the area of fastest development in the future in the paper industry as in other fields of business. As I said, data processing equipment have been used in accounting for many years. The new computers have just recently been available for use in research and engineering. Experience will generate new uses as it always has. The increased mechanization and use of costly equipment will increase the pressure for increased production per machine. A new science in the use of mathematics is developing and high speed computing will be used more and more to operate business. We all know of the new developments in the chemical and oil companies where computers are designed to control complete processes, adjusting the necessary valves and temperatures without human intervention. The steel companies are also working on this same approach for rolling mills and plating processes. It seems natural to me to expect the paper industry, with a similar continuous process of manufacture to be active in this same field of automatic machines under automatic controls. The development of new gages, meters, scales, and all types of measuring devices will accelerate under pressure of the new demand. I feel that data-processing equipment is just entering a new field in the manufacturing industry. The growth will be fast and results will be outstanding as it has always been in a new field. The companies in the data-processing machine industry are actively interested in this field and are eager to work with you to develop this new approach to business management.

Presented at the meeting of the Delaware Valley Section of TAPPI, held in Philadelphia, Pa., Jan. 21, 1960.

Empire State (Metropoliian District)

High Velocity Drying from a Buyer's Viewpoint

K. H. Jones

THESE past few months you have no doubt heard many lectures and read countless articles and ads telling about high velocity drying. Although the process is not new, it is just recently that through technical developments high velocity drying has gained the publicity and recognition it deserves.

The subject has been brought to the front and thrown at us so rapidly that I wonder how many of us know just what to look for in selecting a high velocity drier—such as types, costs, and capabilities. As you are well aware, two articles may look the same, until they are bought and used, proving that custom design, quality, and satisfactory performance cannot be divorced from experience.

I have sold drying equipment from British Columbia to Florida, and from Maine to California throughout the United States, and in my travels have run into some pretty hard-nosed buyers. However, since so-called high velocity driers have come on the scene, the buyer doesn't know what to expect or for what to look.

Tonight, I am going to attempt to put myself in your place in order to help you in your consideration of high velocity driers, that you may know what to look for when choosing this type of equipment.

High velocity is relative. Twenty years ago 3000 f.p.m. was considered high velocity; 15 years ago 10,000 f.p.m., and now we talk 15,000 to 20,000 f.p.m.

As we all know, we have been working with so-called high velocities for many years, and properly applied high velocity driers can do an excellent job.

Where uneven drying occurs across the width of the sheet, a high velocity drier with adjustable features can even out the profile.

As buyers, we should investigate vapor absorption systems, Ross Grewin systems, and enclosing of our present open hoods. Any one of these will give 10 to 15% more drying capacity, with less fuel, less horsepower, and less cluttering up of the drier section.

K. H. JONES, Sales Engineer, J. O. Ross Engineering Div., Midland-Ross Corp., New York, N. Y.

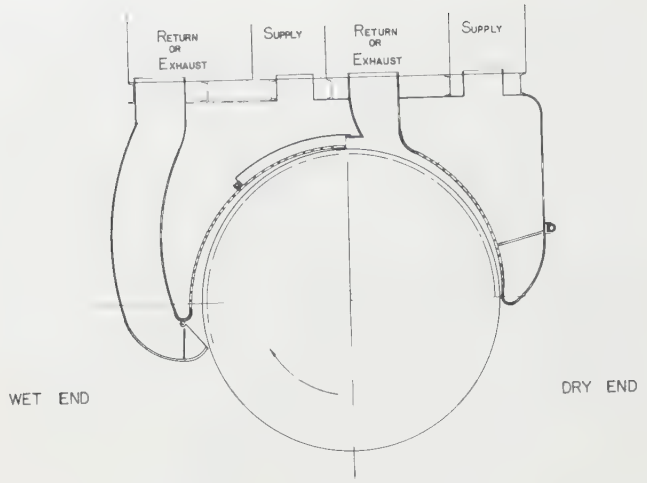


Fig. 1

By enclosing our present open hood, the atmosphere around the drier section can be held very much the same all year round, by adding controls to the exhaust. This, of course, gives us the advantage of the same drying rate and quality with outside atmosphere having very little effect on drying.

Now, after full consideration to these units, we should next consider a high velocity drier.

Figure 1 is a drawing of a high velocity drier installed over 14 years ago by our company—that would be 1946. Several have been installed since. This is a Yankee air system installed over a cylinder with velocities reaching 10,000 f.p.m. This unit was custom designed for a buyer who wanted to exceed the then maximum speed of 1600 f.p.m. It ran over 2400 f.p.m.

You will notice this drier has two separate zones. Air is brought to each zone through supply pipes to a plenum chamber, and directed to the sheet across the full width through nozzles around the periphery of the cylinder.

Return openings are located at the wet end side of each unit for recirculation, or exhaust.

The idea was basic, and the design very successful, but, as you will see, when I show you the latest line of high-velocity driers, technical advances have led to even greater increases in production, efficiency, and potential.

As the buyer, I would want to be assured that the high-velocity drier that I selected had been performance checked in theory and design through exhaustive laboratory tests and finally "proved on the job."

As buyers let us, step by step, become knowledgeable of what we are going to buy.

Figure 2 is a graph made to describe actual tests conducted on one of our high-velocity drier installations, both before and after drying, which should be applicable to our (the buyer's) problem.

This was a moisture test on a machine with 56 conventional steam driers ahead of the size press. We see that for the

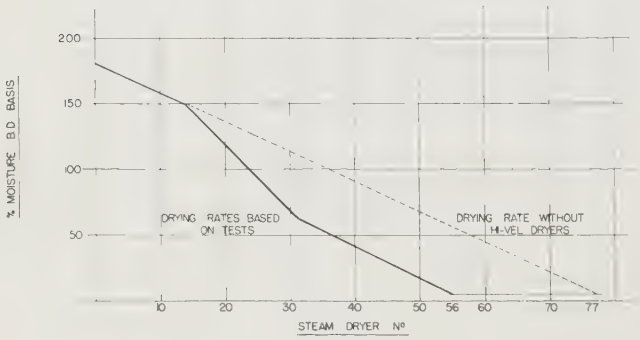


Fig. 2. Moisture test of Ross high-velocity driers

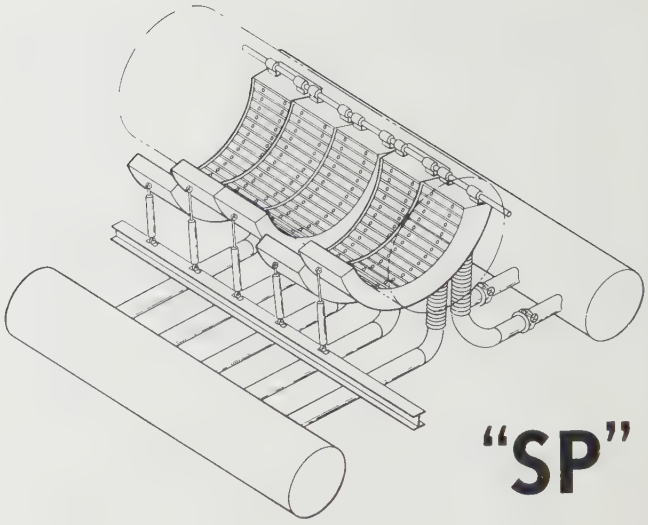


Fig. 3

same production without high velocity driers, 77 steam driers would be required, which means that the production increase would amount to approximately 37%.

This chart shows that the material, a dense, heavy board, entered at 180% moisture-free and after 15 driers, dropped to 145% moisture-free. At this point four high velocity driers are shown. With them, the evaporation rate increased substantially, and after 30 driers, dropped to 65% moisture-free. High velocity drying ended at this point and the material continued under conventional drying, finishing at the 56th drier.

Following the chart with conventional drying through-out, represented by dotted lines, we can see that the rate is gradual to the finish at the 77th drier.

Let us look at the cold facts, or better, hot facts. We find that the installation of four high-velocity driers would replace 21 conventional steam driers. Assuming approximately $15,000 each, our total cost for the steam driers would amount to about $300,000. On the other hand, the four high-velocity driers would cost us about $130,000 completely installed.

In dollars and cents we can realize a saving of $170,000. Being cost conscious, we can include building savings and related utilities, or additional floor space.

The importance and convenience of high velocity drying showed up in one of our recent jobs, where it was necessary to dry coating. The coater was installed between two calender stacks. With the old-type drying, it would have been necessary to move the second stack, perhaps 30 ft., plus extending the building and equipment foundations. With high velocity drying it is possible to dry the coating between the stacks in their present location. We can readily see the tremendous saving realized by this installation.

As a buyer, we should look for the fastest drying, compatible with maximum production of paper machines and coaters. Since the majority of mills are not equipped to do the engineering required, or to decide on this point, and, more important, prove it, we must rely on the engineering service of companies that manufacture driers that we are to select. Therefore, the selection of the right company follows as another important consideration in our decision.

Such information as moisture contents at various points during the drying process, location of the unit to be installed, tightness of draws at this location, weight and grade of paper being dried, speed of the machine, steam pressure in the steam driers, physical space, fuel available, voltage, and other important items in the operation of an efficient, productive high velocity drier should be available. If a supplier does not ask for these items, he is not proposing a properly engineered unit. In other words, any company can provide

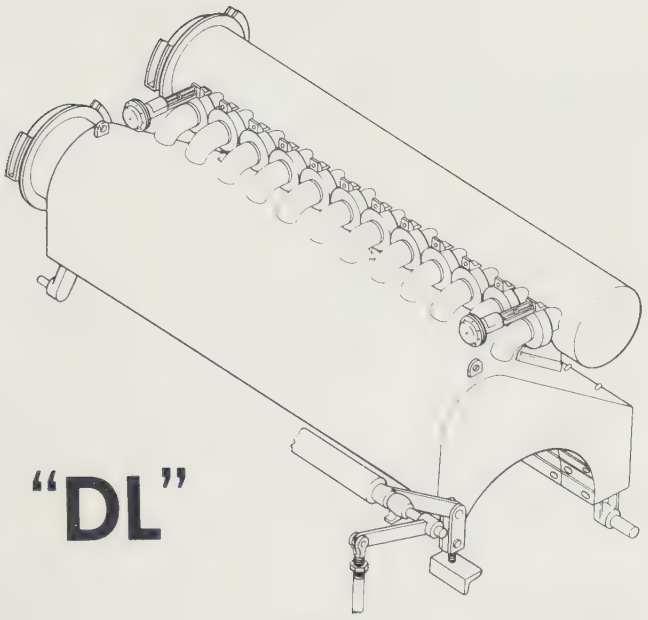


Fig. 4

the ingredients for a high velocity drier, but not everyone can properly engineer such a unit.

As a buyer, we will receive many proposals, some with high prices, others with much lower prices. We'll notice that some call for more driers than others and it will be our responsibility to select the one best suited for our operation.

In evaluating these proposals, we must carefully study how the company plans to arrange the driers, how many high velocity driers are needed, how many steam driers are needed, and other phases of an efficient and productive system.

The only way we can accomplish this is by reviewing previous installations by the company making the proposal, by checking case histories and relying on the experience of the company that has actually made installations points not from just guesswork and experiments—to tell us just how many units are required, and what they can actually do. It is here, again, that we should rely on a firm with years of knowledge and experience for a successful installation.

Of course, the operation of the drier is of great importance to us, and we should have a basic working knowledge of it.

I'd like to use the Ross line of high-velocity driers to illustrate.

Figure 3 is our SP or sectional performanceunit, consisting of individual heads that are separately curved ducts.

These are installed side by side—across the full width of the drier, and can be positioned beneath the bottom driers or above the top driers. Each section may be raised or lowered independently according to the requirements of the material being dried. This is done with the use of hydraulic mechanisms working independently for each separate head.

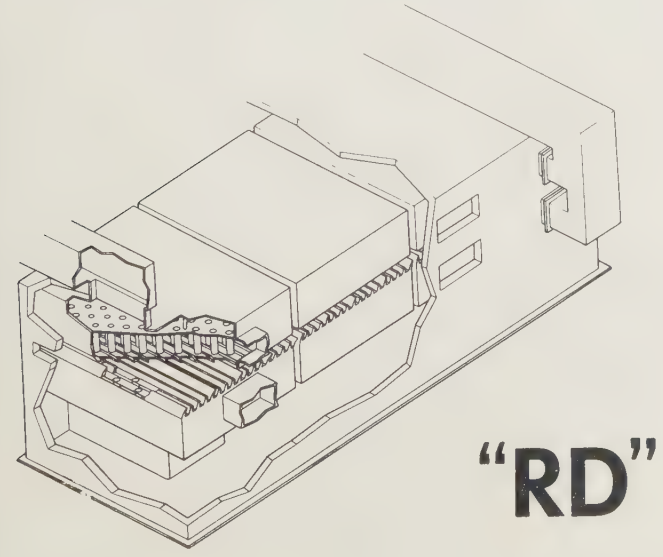


Fig. 5

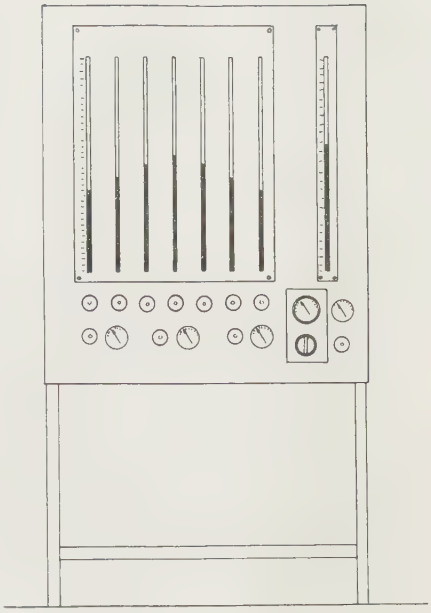


Fig. 6

In addition to controlling the impingement on the web by raising or lowering these heads, the supply air can also be regulated according to the particular moisture condition of the web opposite it; therefore, the air directed at any portion of the web can either increase or decrease the evaporation rate, as desired. Also, since we are able to adjust the velocities across the full width of the sheet, we find that a good deal less maintenance is required at the wet end. Crowns on presses, and so on, can be tolerated longer, due to fact that corrections can be made in the drier section.

Each drier head is divided for supply and return air. The supply air travels through pipes and branches into the individual heads, and is directed to the sheet through slots running parallel to the width of the sheet.

Return air is drawn through pipes between the slots, across the full width, into the return plenum, then, into the return air pipe, where it is returned for recirculation or exhaust.

Since the heads can be moved individually, or all at once, threading, and the clearing of broke is an easy operation.

Figure 4, the DL or Dri-Level type high-velocity drier, is similar to the S.P. unit, except the sections are not individually movable. This unit consists of one solid head running across the full width of the sheet.

This unit is used for very high temperature work and utilizes solid duct connections to each partitioner compartment. The air circulation is the same as for the SP unit.

Once again, the air is recirculated between slots across the full width of the sheet. As soon as it has done its work, it is immediately removed and recirculated.

The D.L. is compartmented across the width. The compartments can be any size, depending on the amount of moisture adjustment necessary for an individual machine. Each supply duct, from the main supply header to each compartment, is equipped with a blast gate, having precision machined blades to assure proper operation at high temperatures. Blast gates are equipped with individual damper motors, operated from a remote console. Damper motors and dampers are located outside the unit for ease of maintenance. The remote console, which I'll discuss later, is equipped with draft gages and also manual air switches that regulate the damper motors to adjust the velocity across the full width of the sheet.

This unit is equipped with quick disconnect, so that, if a break occurs, a valve on the console will disconnect the supply and return connections from the header. During the time it is disconnected, the air will continue to recirculate in the

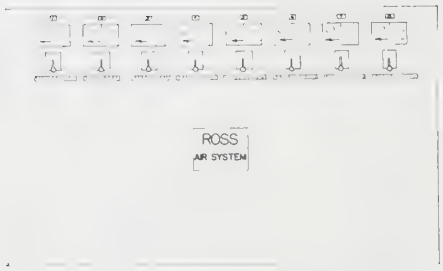


Fig. 7. SP drier console unit

heater, so that after the break is cleared, and the high velocity drier is back in place, hot air is immediately available.

The DL unit uses a lifting mechanism to lift the drier away from the material, during any breaks or threading, and is normally arranged with one air cylinder mounted on the floor for ease of maintenance, and operates a linkage on the front and rear side through a cross shaft. The linkage is arranged with adjustable stops for setting the drier in the correct position to keep the slots at the proper distance from the sheet for maximum efficiency.

Figure 5 is the RD or Rapi-Dri type drier, which is the straight pass type. The material actually can be floated on air, or can be handled on a conventional conveyor. The circulation is somewhat the same as the SP and DL type, with the supply air passing through slots located across the full width, both above and below the material to be dried.

Once again, the return air passes through pipes between the slots, which also run across the full width of the sheet to the return chamber, where it is taken back to the circulating apparatus.

This unit can be made up in zones, so that air temperatures can be varied as the sheet passes through. For instance, in this drier, figuring it as a three-zone, the first zone can be 500°F., the second zone can be 600°F., and the third zone 400°F.

Another feature is the compactness of the unit, which realizes floor space savings of 75%, or more. To illustrate—one of our most recent installations is 16 ft long, and will do the same job as a conventional 90 ft. long drier.

The air-outlet velocities of high-velocity driers range from 15,000 to 20,000 f.p.m., with temperatures reaching 800°F. and over. They can be installed to operate on gas, oil, steam, or bottled gas.

As a buyer, it is important that the purchase of the proper control panel be made for operation and adjustment of moisture control across the width.

Panels differ according to manufacturer and type of drier, but there are certain qualities that should be present in an effective control system. In the selection of these panels, we should check to see that the design is adequate to operate our machine at peak efficiency.

To illustrate, I would like to show you two types of control panels.

Figure 6 is a drawing of a console for the DL type drier. For this particular one, the drier would have seven zones, or compartments. Each is represented by tubes of red liquid, used to gage the pressure in each compartment. By looking at this panel board, we can see a curve as to how the air is being applied to the sheet. This one shows that more air is being provided at the center, and gradually tapering off toward the sides. Since, on a number of machines the sheet is wet in the center and dry on the edges, most air curves would be as shown on this panel. The draft gage shown on the side, by itself, represents the total pressure throughout the entire system.

The dials and meters regulate the various functions of the drier, for the lifting mechanisms, disconnects, recirculation and by-pass dampers, and total system volume control damper.

Figure 7 is a drawing of the console used with the S.P.

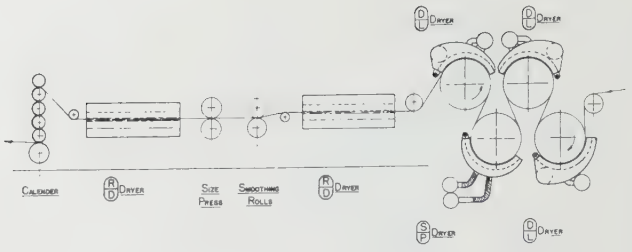


Fig. 8

type drier. Located conveniently for the machine operators, it controls impingement on the web by controlling the distance of the head from the sheet. The gages indicate, by fractions of an inch, the distance that the head is away from the paper, so that at a glance, the operator can tell exactly where each head is located. There is a hand valve beneath each gage, which remotely raises or lowers each section, as required. It is also possible to include draft gages and damper controls on these units, so that volume and velocity may also be controlled to each head.

It would be quite conceivable to connect this console for automatic operation should moisture controlling instruments be available.

Consoles should be designed for the convenience of the workers and should be arranged to suit the customer's specifications.

I've tried to point out a few things tonight that should be considered by the buyer, in selecting the high velocity drier best suited for a company's operation.

I am sure that all concerned with high velocity drying are very enthusiastic over the results and potential of it.

At this point, we would like to mention the future, as I see it.

I've shown you some high-velocity equipment of past years, and high velocity driers of the present age. Now, let's take a look at the paper machine of the future. The machine utilizing the full potential of high velocity driers. A machine that may possibly run at 3000 f.p.m. and produce, perhaps, 200 tons per day.

In Figure 8, you see the machine of the future. Utilizing high-velocity drying to its fullest, the material will enter into steam drums; perhaps, there will be four, and it will be met by a DL drier, then, another DL drier located above the second drier, and SP drier installed on the bottom of the third drier, and another DL set on top of the fourth. The DL and SP driers will be used for adjusting the moisture across the width, so that all moisture corrections have been made, before entering the RD drier. It will, then, pass through an RD drier, through smoothing rolls, the size press, and another RD drier, then on to the calender stack and reel.

This machine will reduce capital investment tremendously, since this type of equipment is much less expensive than conventional steam drums.

Although this machine appears to be a radical departure from conventional drying, it is entirely possible and feasible. The first installation of its type will prove that high velocity drying is out of the infant stage and has matured into a perfect tool for quality. With it, we will realize even drying across the sheet, higher production rates, and savings in capital expenditure.

Presented at the meeting of the Metropolitan District of the Empire State Section of TAPPI, held in New York, N. Y., Jan. 12, 1960.

Pulp Bleaching Conference

Edgewater Beach Hotel

Chicago, Ill.

June 14–16, 1960

Chlorine Tank Car Depletion Alarm and Reserve Supply

HARRY S. FISHER and BRIAN L. SHERA

An uninterrupted supply of chlorine to the bleach plant of a modern pulp mill is of utmost importance. Continuous pulp chlorination will not tolerate any stoppage of the chlorine flow; and the advent of continuous hypochlorite manufacture, or the replacement of all hypochlorite by other bleaching agents such as chlorine dioxide or peroxide, has removed the last batch process wherein the final contents of a chlorine car could be conveniently discharged. Some device is, therefore, needed to indicate when all of the liquid chlorine has been removed from a car, and also a reserve supply must be provided to carry the bleach plant operations until a new, full car can be put on the line.

Reliance on pressure drop is not the answer. Usually, dry compressed air is introduced into the car to raise and hold the pressure at some desired level. As soon as the liquid chlorine has been discharged, the chlorine gas-air mixture will follow—at first at the same pressure as the last of the liquid chlorine. Thereafter, the pressure will drop, but a 30- or 55-ton chlorine car can deliver a considerable volume of gas-air mixture through a 10-p.s.i.g. drop in pressure. This may seriously affect the process, since the gas mixture will flow through the metering equipment and register almost as though it were operating normally, handling chlorine gas alone.

Several balanced devices were observed in which the loss of weight due to cessation of liquid chlorine flow through them set off an alarm. These devices were either too sensitive, due to weight-volume change of chlorine with temperature change, or insensitive because of the "drag" or tension produced on the balanced device by the tubing connecting it to the rigid piping.

It was found that a standard, float-controlled-switch, "Magnetrol" liquid level control with stainless steel trim will serve as the basic alarm device in various types of installations. Several years' operation in chlorine consuming plants has shown the system to be reliable and trouble-free.

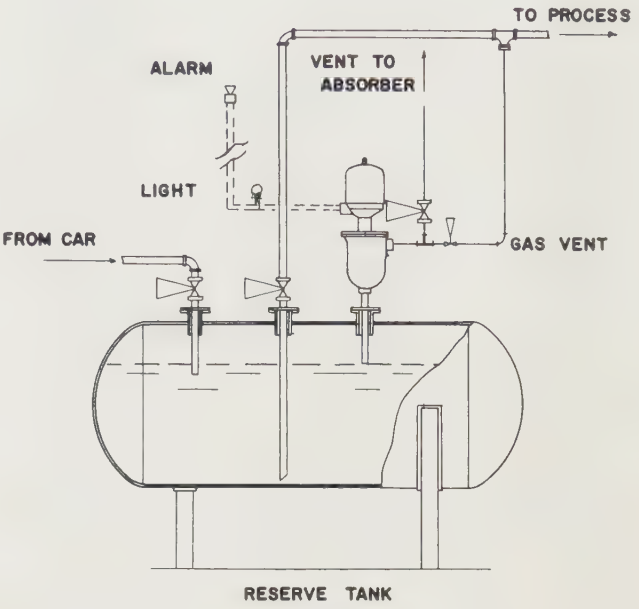
There are several methods of installation to meet various requirements.

RESERVOIR TANK INSTALLATION

Preferred Installation

Experience indicates that it is preferable to install a liquid chlorine flow-through tank, which provides an active reserve when the car has emptied (this tank is sized as required). The Magnetrol unit is activated by the liquid chlorine level in the reserve tank. Reference to the drawing shows that the liquid chlorine is withdrawn by an eductor pipe reaching to the bottom of the tank. The liquid chlorine level is maintained by the dip pipe beneath the Magnetrol unit, which is continuously venting into the liquid chlorine line to the process (the dip pipe must extend into the tank one-fourth of its diameter). Gas formed within or entering the container will escape through the dip pipe and allow the liquid level to rise to the lower end of the dip pipe. Liquid chlorine will follow

Harry S. Fisher and Brian L. Shera, Technical Service Dept., Pennsalt Chemicals Corp., Tacoma, Wash.



into the Magnetrol chamber, raising the float and opening the electrical circuit. Drop in liquid level will activate the electric circuit and the alarms, calling for an investigation. The operator will open the vent line to the absorber for a few moments to be assured that it is not simply an accumulation of gas which has dropped the liquid level. Upon determining that the level drop is due to cessation of liquid chlorine flow from the car, he will turn in the flow from a full car. This will push forward a gas mixture from the empty car line, which is vented to the absorber until the liquid level has raised the Magnetrol float and the system is in order again to discharge the full car.

The continuous venting of the magnetrol float chamber is an important function. Chlorine gas may form in the container and must be relieved to permit proper operation. The relief may be handled by manually setting the opening on a small, tapered, plug-type valve. The venting flow through the valve should not be much greater than required for discharge of the occasional gas formed.

These systems will give false alarms if the flow of liquid chlorine is stopped for an extended period, especially under warm ambient conditions. Venting upon startup will immediately correct this situation.

The absorber referred to, into which the chlorine gas-air mixture from the drum can be vented rapidly by manual operation, will vary according to the type of plant using chlorine. In the case where hypochlorites are prepared, the gas mixture can be vented into the alkali solution tank. In other cases, if there is no process use for the gas mixture, the chlorine may be absorbed in a caustic soda solution or lime slurry.

The steps for operation of this system are:

(*a*) *New, Full Car Turned into the Line.* Vent to the absorber until the chlorine liquid level has raised the Magnetrol float. Close the absorber line and set a small flow through the Magnetrol chamber vent.

(*b*) *Alarm Sounds, Signaling "Empty" Car.* Open for a few moments both the line to the absorber and the Magnetrol

chamber vent. If the alarm stays on, shut off the empty car, turn in the full car, and proceed as in (*a*).

PIPELINE INSTALLATION

Alternate Method

The Magnetrol is installed on a side branch on the vertical, liquid chlorine pipe from the tank car. Cessation of liquid flow will no longer provide support for the float, and the electrical circuit will be activated. This electrical impulse can set off an alarm and activate any number of other operations, such as:

(*a*) Closure of an automatic valve, stopping gas flow from the empty car and turning in liquid chlorine from a full car.

(*b*) The same operation as (*a*) except that the liquid flow is turned on from a reserve chlorine ton container. The operator will then turn in the flow from a new car and shut off the flow from the ton container.

It is cautioned that line-mounted units sometimes alarm prematurely, as some tank cars discharge intermittent volumes of gas before all of the liquid chlorine was emptied out.

Experience has been with Magnetrol liquid level control No. 244; equivalent type equipment would be suitable.

Received Aug. 17, 1959.

Comparison of the Air Doctor and Blade Coating Methods

G. L. BOOTH and N. H. LAUGHREY

Technology of coating processes is advancing rapidly. Since the renaissance of the coated paper industry brought about primarily because of Peter J. Massey's (*1*) concept of a roll coater commonly called the "Consolidated" coater and Killey Terry's (*2*) development of the air doctor which is known as the "Warren" air doctor, the technology of coating and coating machinery has advanced at an ever increasing rate.

In recent years the development of a blade coater utilizing methods similar to those disclosed in the Trist patents (*3–5*), the coated paper industry has begun a second revolution within a very few years.

The object of this paper is to compare the air doctor coater and the blade coater, taking into consideration the various types on the market, performance, operating characteristics, coating quality and coat weight. A more comprehensive study than that of this paper would include roll coating and bar coating.

The paper is divided into three sections as follows: (1) air doctors, (2) blade coaters, and (3) summary and comparison of these two methods.

AIR DOCTORS

We shall commence with a discussion of the air doctor. The two most commonly used air doctors in the United States today are based on the Terry patent and the combined Dickhaut (*6*) and Pomper (*7*) patents. There are, of course, many other air doctors in use in the United States which include the Ozalid, the Egan, the Trumpp, the Jagenberg (*8*), the Marsh, the Birch and other air doctors. Fundamentally, most of these are outwardly the same in that an excess of coating is applied to the sheet by a slowly rotating roll whereupon the sheet is directly exposed to a controlled blast of air which removes the excess and leaves the desired amount of coating on the sheet normally pattern free.

Operationally, most of these units can be considered true air doctors although some are used as air brushes. Drawings have not been prepared on all of these doctors.

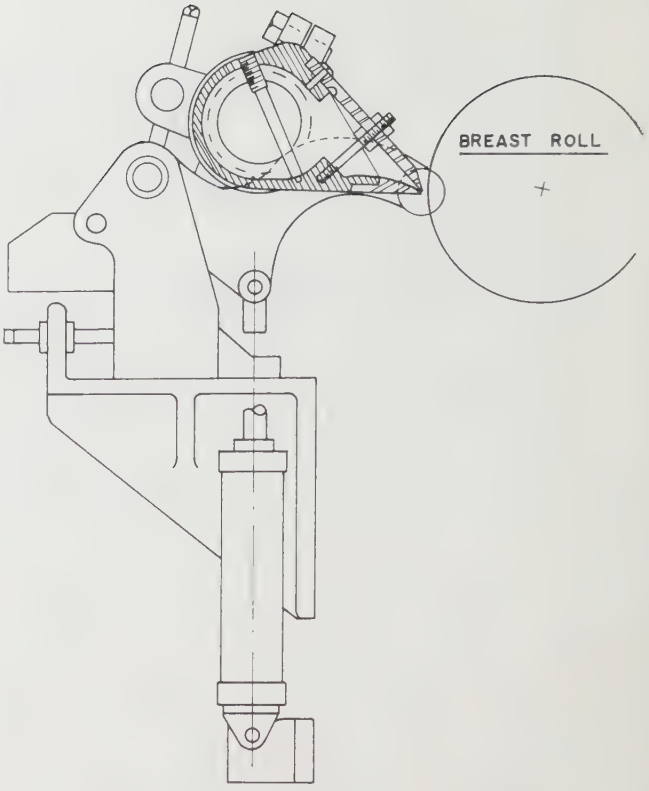


Fig. 1. Terry air doctor, patent 2,139,628

Figure 1 shows a cross section of the Terry air doctor. As you might realize, a true venturi has a curved approach to transform pressure to velocity. This is the most efficient means by which the transition can take place. However, when this is attempted over a wide width such as the linear orifice of an air doctor, it becomes an almost impossible thing to manufacture. Therefore, for expediency in manufacturing, the bottom lip has a radius which is designed to give efficient transition from pressure to velocity. However, the top blade in this air doctor is flat and is *deliberately* flat in order to make manufacturing and control of blade setting easier. Adjustments of blade opening is controlled by the push-pull device spaced every 4 in. across the face of the blade. The cross section of the air doctor is cast in a general teardrop shape which is designed again for efficient air handling.

The outside top and bottom of the doctor is as clean as possible to give efficient flow of secondary air to sweep the blades and keep them clean by preventing buildup of coating.

The normal vertical, horizontal, and angular adjustment of the air doctor is built into the brackets and will not be discussed.

Figure 2 shows the Pomper air doctor. You will note that the cross section of this air doctor is essentially the same as that of the Terry doctor. Means of lip adjustment are somewhat different although the end results are the same. In this case, a tube is used rather than a cast body which is quite acceptable and in no way impairs the efficiency of the unit.

The particular design of doctor is such that the impingement of air is more nearly tangent than the previous unit.

The Egan, Marsh, and Jagenburg (*8*) air doctors would all fall into the same category as the above units. Since these units are all very similar to the above doctors, no discussion will be attempted.

Figure 3 shows the next unit, the Ozalid air doctor. Blade adjustment is from the rear of the unit as shown. This particular unit makes no attempt to have a radius on the blades since it is used primarily for a brush type of coating operation.

Since the air pressure used for brush operation is usually

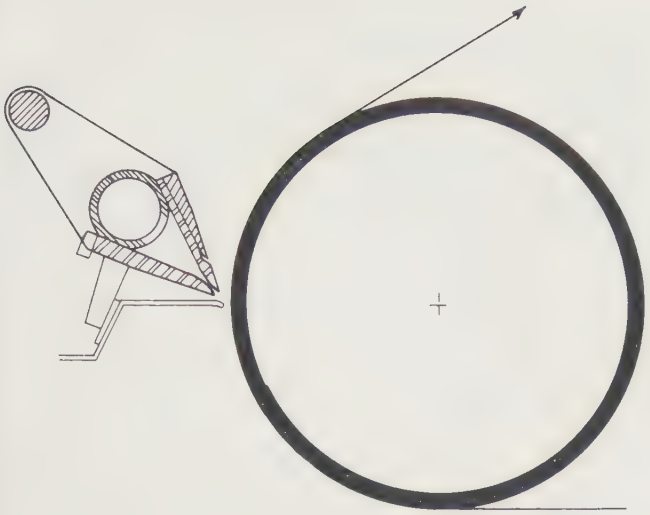


Fig. 2. Pomper air doctor, patent 2,679,231

considerably lower than that used for true doctoring operation, the efficiency of transition from pressure to velocity is not as important.

The Trumpp and Birch air doctor more nearly approach the brush type of operation. At this point it would be well to define the difference between an air doctor and air brush. Various opinions have been expressed on this subject, so no doubt there may be some question as to the validity of the following. An air doctor is a unit which impinges a knife-like stream of air both to meter and physically to remove the excess coating from the sheet while leaving the remaining coating smooth on the sheet as it passes through the knife zone. An air brush smooths the coating on the sheet, but does not physically remove any excess coating. The coating usually cascades down the web.

Some schools of thought consider only the way in which the jet of air issues from the nozzle saying that a true knife will have one sharp converging point (laminar flow) whereas a brush stream issues more in a spray of air (turbulent flow).

All air doctors used for clay coating operations can be considered to be a form of air doctor. Virtually all of the units used for diazo coating and the like can be considered fundamentally air brushes. It is realized there will be an overlapping of these two, and it is a fact that the air doctor can be used as an air brush through reduction in air pressure, angle of impingement, opening of the blades, and other such adjustments. However, a unit designed only for an air brush operation cannot satisfactorily be used as an air doctor. Normally air brushes will be run with a pressure which is measured in inches of water, or ounces per square inch and almost always they will be operated at speeds from 50 to 300 f.p.m. Air doctors on the other hand will be operated with $^1/_2$ to 5 p.s.i. pressure and at speeds in excess of 1000 f.p.m. Since the interest is in the air doctor rather than air-brush operation on clay coating, the rest of the discussion of air doctors will be limited to the clay coating phase.

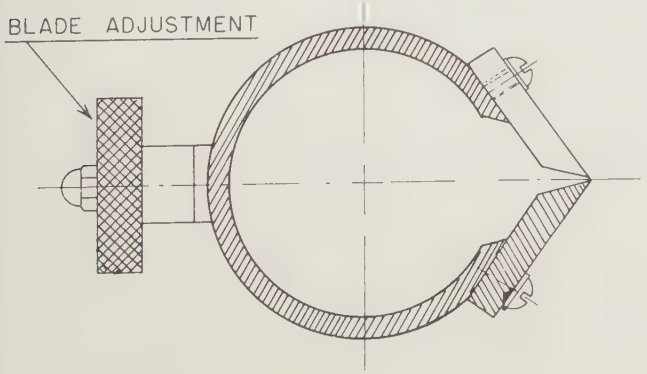


Fig. 3. Ozalid air knife

Normally an air doctor will operate at speeds from 500 to 1200 f.p.m. applying coatings 35 to 45% solids average and in a coat weight range of 6 to 18 lb. per book ream. The coating uniformity which is normally expected is plus or minus 5% with some operations being controlled as close as ±2%. Tolerance of coat weight across the web is ordinarily controlled within the same range. Extremes in coating solids will range from 0 for wash coats up to as high as 60% when using special latex binders. Normal coating viscosity range is from 50 to 400 cp. Coat weight is controlled basically by air pressure in the air doctor. In some cases speed of the color roll has a secondary effect on coat weight. Speed of the machine will influence coat weight when all other conditions remain constant. Coating solids will of course change the range of coat weight that can be put on using given settings on the air doctor. Ordinarily once the orifice opening is established and the position of the air doctor is established in relation to the breast roll, the unit will not be altered for various coatings. The orifice opening is usually in the neighborhood of 0.018 to 0.018 to 0.035 in. depending on the product being run and coating color characteristics.

If it is found that the air doctor does have to be changed quite frequently in attitude or position, it is a sign that the air doctor may be somewhat susceptible to small changes in the rheological properties of the coating.

Typical products made on an air doctor include the normal grades of offset, litho, label, the general ranges of printing papers, bleached board and boxboard. Certain metallics and high grade printing papers are made with air doctors. Diazo coatings and other types of photosensitive coatings are usually made using an air brush coater.

BLADE COATING UNITS

Blade coating is the application of coating by the use of a flexible blade. The fluid mechanics actually taking place in the blade area is still not fully understood. It is felt that the hydraulic force of the coating does tend to flex the blade thus forcing a certain amount of coating through. This type of coater is well adapted to high solids coating, although its range is from 45 to 70%. Dispersions appear to be unlimited in the adhesives used and may include such binders as starches, gums, glues, proteins, latices and other synthetics. Blade coating is not limited only to dispersions but can conceivably include such solutions as lacquers and varnishes. Water emulsion materials such as the various latices may be applied by this method. Certain lacquer solutions may be converted to dispersions by emulsification and so coated by this method. It is not far amiss to be thinking in terms of hot melts such as the waxes or resinous materials used in

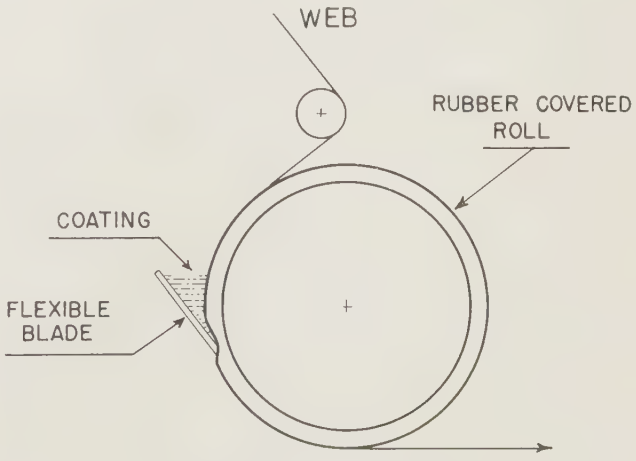


Fig. 4. Trailing blade coater, Trist patents 2,368,176, 2,593,074, 2,796,846

functional coatings. The origin of blade coating is nebulous. In patent searches, it has been found that various phases of blade coating dates back many years. The Trist patents revitalized the idea and within the last decade, blade coating has developed rapidly. The Trist coater was the name of the machine by which it was known until a few years ago when the term "trailing blade" was accepted by the industry. The process will be referred to as blade coating in the remainder of this paper. The various types of blade coaters will be cited by patent where possible.

Type 1: Trist Patents

Figure 4 shows the coater construction disclosed by the Trist patents. It is now commonly referred to as the trailing blade coater. The color trough is in a position horizontal to the backing roll and loaded with coating from a manifold above.

The blade is locked in a holder made especially for this coater and backed up by a heavier or thicker blade for support. Normally, best results are obtained by using thin caliper blades in the range of 0.012 to 0.015 in.

The whole trough and blade swing on an axis around the journal of the rubber-covered backing roll, being counterbalanced by weights that offset the weight of the coating. The solids, viscosity, physical characteristics of the sheet and speed of the machine are factors that control coat weight in most blade coaters. Coat weights are in the low range, usually between $1^1/_2$ to 4 lb. per ream. Higher coat weights have been achieved.

Type 2: Rush Patent

Figure 5 shows the blade coater disclosed in the Rush patent (*9*). Very little is known about this machine to date, although the rudiments of the blade coater are the same.

If the web travel is followed, it will be seen that the coating is picked up by kiss application (single or dual) and the excess is doctored off. The same principle applied as in the former projected machine, i.e., the greater the viscosity, the greater the hydraulic force to flex the blade open. The excess coating is doctored off on the backing roll past the kiss pickup and returned to the supply system. This operation necessitates the screening of the returned coating to free it of foreign material picked up in its circulation. Little is known as yet as to what blade thicknesses are effective, the coat weight range, practical speeds, etc.

It would appear that coatings would have to be tailored to these machines explicitly for the grade being made as well as the speed at which the desired amount of coating weight is to be deposited. Speed must be dictated by the coat weight desired, and the feeds by solids and adhesives controlling the viscosities.

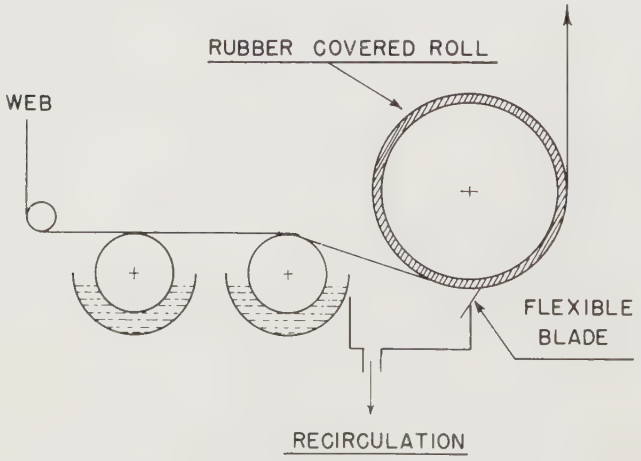


Fig. 5. Trailing blade coater, patent 2,746,877

Type 3: "Flexiblade"

Figure 6 shows a controlled blade coater, some features of which are disclosed in the McGladrey patent. This is a comparatively new machine to the industry, also, and somewhat radical in design from the preceding units. In the print it can be seen that the coating head, which includes the coating chamber as well as the blade holder, lifts vertically to the backing rubber-covered roll. This is known to be an advantage in that quick retraction of coating can be made in the case of a web break on the machine.

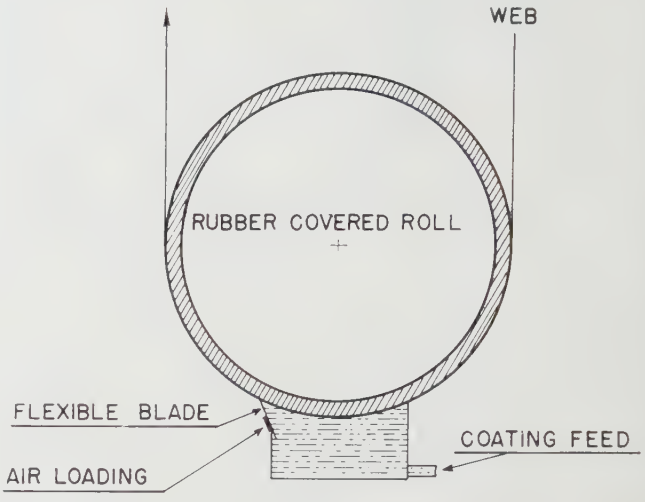


Fig. 6. Flexiblade coater, patent 2,285,531 and pending

The principle of coating remains the same as in the other units but this type of coating is capable of compensating for the hydraulics of the coating action. It will be noted from the diagram that there is a pneumatic tube in the blade holder that controls the amount of coating passing the blade. In this pressure loading, coating hydraulics do not dictate the speed or coat weight but rather a control is put in the hands of the operator allowing him to control coat weight compared with speed. An example is necessary: Suppose the operator is running at 900 f.p.m. using a 60% solids, starch bound, clay dispersion and the tour boss wants 1100 f.p.m. with no change in coat weight. They were coating with 30 lb. of air on 0.020-in. flexible blade at 900 f.p.m. and getting 6 lb. per 3300 sq. ft. At 1100 f.p.m. without changing anything but coating demand, but adding perhaps 15 lb. more air loading on the blade, they could control the coat weight at 6 lb. per 3300 sq. ft. The range of coat weights is not limited to 6 lb. per 3300 sq. ft. This coater has experimentally deposited from $1^1/_2$ to 21 lb. per ream on various grades of paper and board.

The blade is readily accessible and easily removed or replaced in less than a minute. Its advance or retraction due to wear or adjustment is equally easy by a single adjusting bolt on the front of the blade holding mechanism.

Blade thickness in this design is dictated by viscosity and solids of coating color. It has been found that in the heavier viscosity coatings it is possible to coat through a greater range of weights using a moderately heavy blade, namely, 0.020 in. As the viscosity drops off, the lighter blades come into play—0.016 to 0.012. Heavy coat weights using low viscosity coatings are not easily controlled on this coater.

BLADE COATERS—GENERAL COMMENTS

One phase of blade coating that should not be overlooked is the sizing treatment and the density of the web being coated. It stands to reason that a slack sized news sheet is going to pick up more coating than a hard sized dense top liner on board. Some sheets may actually dehydrate a coating thus

building up coat weights on the substrate in proportion to the solids in the coating itself. It is felt that this study would allow a wonderful research problem for some institution.

Little has been said so far on the sheet prior to blade coatings. This can be said, however: the rougher the top surface of the web, the more clay that will be packed into the valleys, leaving the hills with little or no coverage. After calendering a mottle will show up as a result of packing. As the sheet approaches a smoother surface along with better formation, the blade coaters do a better job in uniform application of coating colors. Smoothness is merely a relative term and to produce a smooth sheet with blade coaters, one has to start with a relatively smooth web of paper. It is a fact that a rough surfaced sheet will, when coated by this method, end up with a flatter more even surface but the mottle may be evident, whether calendered or not.

Tandem coating has been considered where two of the same or different coaters could be used.

Streaks are common to all blade type coaters and are usually attributed to foreign material lodging itself behind the blade. These particles may be dried clay, uncooked protein or starch, surface fibers, felt hairs or numerous other materials. Screening of the coatings is of course a prerequisite and filters in the supply lines should be considered part of the equipment. Surface fibers and felt hairs should be laid down by a press section or calender ahead of these coaters.

SUMMARY

In summary, the obvious question is when should an air doctor be used and when should a blade coater be used.

Let us consider the air doctor first. It is highly impractical to employ an air doctor at low coating solids on a paper machine running at high speed, primarily because of the drying problems. Secondly, to our knowledge an air doctor has not yet been used at speeds in excess of 1200 f.p.m. and it is therefore questionable whether the unit would perform satisfactorily at speeds in excess of this. Indications are that it would, but it is felt that the terminal speed would be lower than that of the blade coater because of coating atomization at the point of coating removal by the doctor. This is aggravated at elevated speeds due to the need to proportionally increase the air pressure of the doctor to maintain coat weight. On the other hand, an air doctor is a machine that will apply coat weights in excess of 15 lb. per 3300 sq. ft. Also, on cylinder machine board making a lined sheet and having a rough surface, the air doctor is preferred because of streaking problems with a blade coater.

The negative features of blade coating operation are its inability to coat satisfactorily a reasonably rough surface such as cylinder board and, in some designs of blade coaters, the inability to apply high coat weights. Further, in most instances, the blade coater is more prone to streak problems, as pointed out earlier. This certainly does not imply that the air doctor has no streak problems. The air doctor will streak because of a dirty or nicked blade, but not because of surface roughness.

Let us now consider the coated surface and quality that is obtained from these two methods. First, the air doctor is a contour coater and will apply a reasonably uniform coating to follow contour of the sheet. Since this is the case, an air doctor coated sheet is excellent for litho printing operations. This does not imply that a blade coated sheet cannot be used for these processes provided sufficient coating is applied to the sheet. A blade coated sheet is superior for rotogravure printing. It is also equally as good and probably superior to an air doctor coated sheet for letterpress operation.

In the final analysis, the decision to use a blade coater or an air doctor coater will rest with the user. Factors such as location on a paper machine or as a conversion coater, coating quality, coating weight, speed, paper or board to be coated, end product and future market will influence the decision.

To recap, the air doctor is relatively streak-free, has low maintenance, applies heavy coat weights, and applies an even thickness which is good for functional coatings. It requires low viscosity and thus usually low solids coatings and further requires supercalendering for a smooth surface.

The blade coater will handle high viscosity color and consequently high solids; it is excellent for high speeds, produces a level surface ideally suited to printing, and since the surface is flatter, it requires less calendering.

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Received Mar. 9, 1960. Presented at the 10th Coating Conference of the Technical Association of the Pulp and Paper Industry, held in Boston, Mass., May 25–27, 1959.

Welded Tanks and Vessels for the Pulp and Paper Industry

ROBERT A. JACKSON

It is the intent of this paper to review a few aspects of the design and construction of tanks and vessels for the pulp and paper industry with particular reference to those problems that are peculiar to this industry. Through a better understanding of certain practices now common, it is hoped that it will be possible for engineers in the pulp field to modify these practices to ensure better structures from the viewpoint of both economy and safety.

The discussion which follows is necessarily somewhat general but it must be borne in mind that some of the considerations mentioned with respect to a particular type of tank may be equally applicable to other types.

FLAT BOTTOM VERTICAL ATMOSPHERIC PRESSURE TANKS

Assuming that capacities of required storage have been decided, the first question facing the engineer is the selection of tank sizes. Unlike his counterpart in the petroleum and water works industries, the pulp and paper industry engineer has no standard tank sizes to guide him. As a result, a large number of tanks in a pulp mill may be found varying only a few feet in diameter and height. Proper selection of tank dimensions and grouping of tanks having reasonably similar capacities would provide either savings in first cost or added storage capacity at no added cost. For example, it would not be unusual to find specifications for a new kraft mill calling for these liquor tanks:

3—35 ft. diam. by 35 ft. high, weak black liquor
1—35 ft. diam by 28 ft. high, green liquor
2—38 ft. diam. by 28 ft. high, white liquor

Changing each of these six tanks to 35 ft. 8 in. diam. by 32 ft. high (each having the capacity of the largest tank above) could result in a saving in first cost of about 5%. Or, to put it another way, about 100,000 gallons additional capacity is obtained at no added cost. Since tank standardization—whose purpose would be to provide economies such as this—is not available in the pulp and paper industry, the advice of

Robert A. Jackson, Chicago Bridge & Iron Co., 1318 Fourth Ave., Seattle 1, Wash.

responsible fabricators would be helpful in determining the most economical tank sizes.

After the tank dimensions have been selected, the proper construction specification should next be established. Though there are engineers who establish no specifications for design and construction and who leave the entire matter to the imagination (and honesty) of the manufacturer, it is more common in the pulp industry to make reference to the American Petroleum Institute (API) Specification 12C (*1*) or, in a few cases, to the American Water Works Association (AWWA) Specification D100-55 (*2*). In the writer's opinion, modification in the design stresses of either of these should be made for pulp mill tanks.

The API 12C Specification is written exclusively for use in the petroleum industry. This is clearly set forth in Article 1, Scope, where it states: "This specification is designed to provide the oil industry with tanks of adequate safety and reasonable economy, for use in the storage of petroleum and its products and those other liquid products commonly handled and stored by the various branches of the industry." The most important fact to be remembered with regard to the API Specification is that it provides for a relatively high design unit stress based upon a water load with the recognition that the actual stress under service conditions is considerably less. Most petroleum products have a specific gravity of about 0.85. For the usual service condition, therefore, the permissible basic design stress of 21,000 p.s.i. for water (specific gravity 1.00) is reduced by the ratio of the specific gravity of the usually stored product to that of water to a working stress of 17,850 p.s.i. When the pulp industry specifies construction in accordance with the design values in the API 12C Specification for tanks storing pulp mill liquors, it must recognize that it does so at the expense of lowering the factor of safety to 2.85 or less in tension for the commonly used carbon steels.

The AWWA Specification is an improvement over the API 12C Specification with respect to the above objection in that a more reasonable permissible design stress is specified, i.e., more consistent with the higher specific gravity liquors encountered in the pulp industry and more consistent with a factor of safety used in such construction. It is, however, properly somewhat conservative since it deals with tanks storing community water supplies—a matter affecting the health and safety of the community at large. It would appear reasonable that, within the limits of adequate safety, somewhat higher design stresses be permitted for industry tanks as has been done in the petroleum industry. So long as relatively small tanks are involved, the economic effect of the more conservative design stress in the AWWA Specification will not be great since practical minimum plate thicknesses will control. However, whenever the industry may require large storage tanks, a too conservative design stress results in more costly storage.

In the interest of economy for industrial tanks storing noncorrosive liquors, the use of a higher design stress than set forth in the AWWA Specification seems warranted. For the commonly used carbon steels in noncorrosive liquor service, it is suggested that a basic design stress in tension of 18,000 p.s.i. reduced by the usual 85% joint efficiency for welded construction be used for vertical tanks.

For corrosive liquors, a more conservative attitude would seem appropriate. For acid, caustic, or other corrosive liquor service, a basic tensile stress value of 16,000 p.s.i. reduced by the joint efficiency and exclusive of any corrosion allowance is suggested. Obviously, for liquors heavier than water, proper account of the higher specific gravity should be taken. It should be noted that both the API 12C and the AWWA Specification now require full penetration welding of secondarily stressed joints (horizontal shell joints of vertical tanks, for example) wherever plate thicknesses are $^3/_8$ in. or less. It is recommended that for caustic and acid tanks this requirement be extended to shell plates thicker than $^3/_8$ in. where the API and AWWA now generally permit two-thirds penetration welding.

Certain details of construction commonly used in pulp mill tanks require critical inspection and review. For vertical storage tanks, the one critical area where stresses are indeterminate is at the junction of the shell and bottom plates. It is better to avoid placing nozzles or other fittings in a location that would interrupt the continuity at this juncture. If unavoidable, care should be taken to fully reinforce such openings. For large interruptions of continuity, it is good judgment to stress relieve the fitting after fabrication with a part of the shell plate to which it attaches. The elimination of square corners on tank openings is extremely advisable. High notch stresses can exist at such corners and self-propagating cracks can and do start at these points of high stress. In extreme cases, complete collapse of the tank can result. It is better to specify rounded corners. While the corner radius will vary with the size of the opening, a minimum radius of 3 in. is suggested.

CERAMIC LINED ATMOSPHERIC PRESSURE TANKS

There is no satisfactory design theory for establishing the proper steel shell thickness of ceramic lined nonpressure tanks. For vertical tanks, designing the shell for the static loads using stresses as discussed earlier will usually result in shell thicknesses too thin to permit the shell to perform satisfactorily its function as a form for the tile lining. Here, deflection may be more critical than stress. Examination of a number of successful nonpressure ceramic-lined tanks indicates that the stress in the bottom shell ring, ignoring the effect of the tile lining and considering only hydrostatic stresses, is in the neighborhood of 6000 p.s.i. on the gross section. Until a better theoretical approach is evolved, it is suggested that the shells of such tanks be designed for 6000 p.s.i. at 100% joint efficiency in the bottom ring and that this plate thickness then be used for the entire shell of the structure. One-quarter in. plate should be considered minimum. For relatively large diameter tall structures, it may be permissible to decrease the shell thickness in the upper rings but keeping the 6000 p.s.i. unit stress as a guide to good judgment.

For ceramic lined horizontal tanks, available theory for unlined nonpressure and for unlined pressure (*3*) tanks may be used as a guide to the designer's judgment. Here again deflection may be more critical than stress. Out-of-roundness tolerances may be critical and this, as well as the plate thicknesses used, should be a matter of agreement between the owner, fabricator, and lining contractor at an early stage of design. To avoid difficulties from differential deflection of multiple supports, it is suggested that horizontal tanks be supported on only two supports placed as close to the ends as practicable to take advantage of the stiffening effect of the heads. Ring girders at the supports as well as intermediate stiffeners are frequently necessary.

PRESSURE VESSELS

For unlined pressure vesels above 15 p.s.i. design pressure, the American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code (*4*) provides design criteria and fabrication requirements. Most states require such vessels to conform with this code. However, within the past few years it has been generally recognized that the design of ceramic lined welded pressure vessels may not be adequate if ASME Code requirements for the design pressure alone are considered (*5*, *6*, *7*). The winter 1958 addenda to this Code, providing for 100% joint efficiency for fully radiographed vessels and resulting in thinner shells, only serves to emphasize this matter. For such ceramic lined vessels, steel plate thicknesses are usually a function of various operating temperatures, the operating pressure (as distinguished from the design pressure), lining thickness and type, and the

dimensions of the structure. These factors must be known or estimated as accurately as possible to determine the proper and most economical steel shell design. Errors of 20% in estimating certain of the temperatures involved, for example, can result in either more expensive initial capital expenditure or costly repair expenses. Obviously, the determination of these operating and design factors should be the responsibility of the owner or his engineer rather than that of the vessel manufacturer. In addition, ceramic lined pressure vessels will ordinarily require roundness tolerances more restrictive than imposed by the ASME Code. This tolerance should be a matter of agreement between the parties concerned but it should be recognized that unnecessarily severe restrictions can seriously affect the cost of the structure. For most sulfite digester construction, a tolerance of $^3/_4$ in. between maximum and minimum diameters appears to be a practicable requirement. It is preferable that the tolerance be expressed in terms of the diameter rather than the radius since it is difficult to establish the true centerline of the completed vessel from which to measure radii.

A number of vessels falling within the pressure range from slightly above atmospheric to 15 p.s.i. have not heretofore been covered by any national standard. The recently issued API Standard 620 now fills this gap (*8*). A blow tank is an example of this low pressure group. Its construction should accord with this fact and might be specified to comply with API Standard 620. For instance, a recent trend toward using blow nozzles having distorted shapes or entering into box arrangements with large flat plate areas is not advisable for pressure vessel construction. While there may be process advantages for using elongated or box shapes for these nozzles, it is better to make a compromise in these shapes rather than risk a serious failure of the structure.

ELEVATED STRUCTURES

It is not infrequent to see specifications requiring elevated tanks and bins to be designed in accordance with the API 12C Specifications. Besides the objections to the use of this specification raised above, the API 12C Specification is not intended to apply to elevated tanks. On the other hand, the AWWA D100 Specification does apply to elevated tanks and its use for the design and construction of elevated pulp mill structures appears reasonable.

Pin-connected rods with turnbuckles are preferable to angles or other structural members as sway bracing since they can be used to plumb the structure and may be tightened at a later date if necessary. Elimination of diagonal sway bracing (or its later removal) in one panel destroys the effectiveness of the balance of the sway bracing and is, therefore, inadvisable.

OTHER CONSIDERATIONS

It is not the purpose of this paper to elaborate on fabrication and erection standards. Certainly an owner should specify and insist on work being performed to at least the minimum fabrication and erection standards of the API 12C, AWWA D100 or American Welding Society D5.1-52. Too often these minimum requirements are not specified or adhered to. For example, tanks are not infrequently erected without any attempt to check on welding quality such as sectioning or spot x-raying. It should be apparent that welding quality is basic to the integrity of the tank. Is it fair to speculate on the result were the pulp industry's customers similarly unconcerned about the quality of pulp?

No discussion on tanks could omit some mention of the importance of good foundations. Differential settlement under the tank shell from inadequate foundations can, at the very least, cause unsightly buckles (usually in the top rings) and contribute to excessive maintenance costs. If of a sufficient order of difference, complete collapse of the tank may result. It does not seem rational to make a large capital expenditure for a storage tank and, at the same time, risk that expenditure by a relatively small economy in the foundation.

With proper engineering attention to design details and specifications and insistence on adherence to those specifications, the pulp industry will benefit from safe, trouble-free structures. The timely advice of responsible fabricators will be of considerable assistance since they are as concerned with this matter as are owners. It is hoped that this paper will be helpful to engineers in their understanding of a few of the basic considerations in design and construction of tanks and vessels for the pulp and paper industry.

While these observations represent only the writer's opinion, he makes no pretense of originality. He is indebted to his many associates in Chicago Bridge & Iron Co. and, over a number of years, to A. Quinn of Stebbins Engineering Corp., for his advice and assistance with regard to ceramic-lined structures.

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Received Oct. 30, 1959. Presented at the 14th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Pittsburgh, Pa., Oct. 12–15, 1959.

Flexible Packaging Material Factors in Automatic Packaging

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Whether it is a sheet of cellophane, paper, paper plastics combination, or straight resin extrusion film they all have one thing in common, on automatic packaging equipment, they must all run successfully.

In the course of the normal trial-and-error method of determining whether or not a given piece of flexible packaging material will operate under production conditions on automatic packaging equipment certain bits of knowledge are learned. This knowledge is not always learned systematically but rather on a practical day-to-day basis. Because of the urgency at the time of the trial-and-error testing, the same urgency that packaging has in general, it is not the concern of those in the midst of the test to really define and pinpoint just where various problems lie, or to spell out the specific problems. With the advent of so many new plastic films the problem as a whole suddenly resolves itself to the point where the automatic packaging equipment should be mentally taken apart and subdivided into its various components and each of the elemental parts of the components described, with

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enough detail to pass on to those who are responsible for the manufacture and quality control of packaging materials.

SIX MACHINE COMPONENTS

Because of the great variety of industries supplying materials for packaging it is not easy to use universally acceptable terminology. It is therefore perhaps best to go ahead and specify factors concerned in overwrapping equipment in the same terms as used by the manufacturer and user of this equipment. In attempting to analyze cut-to-size and self-measuring wrapping machines and form and fill-bag machines for operational factors we must primarily keep all three styles of machine in mind simultaneously. In doing so we arrive at a breakdown of six component considerations.

Perhaps a little explanation of cut-to-size and self-measuring in relation to packaging equipment should be made. The cut-to-size term in this instance is strictly related to the type of overwrapping machine where the wrapper, in register, is cut to a specific length before coming in contact with the product. A self-measuring type of machine, typical of which today is the bread-wrapping machine, has a self-measuring nature in that the web of wrapping material runs around the full girth of the product before it is cut-off. Both of these types of overwrapping equipment have similar cousins in the bag form and fill type of machine.

The first of the six components to be considered, naturally, would be the paper feed, the actual first contact of the packaging materials with the automatic machine.

The second in line would be the cutoff mechanism. Roll stock, which is most universally used, at some point must be severed to go on its way as part of the finished package.

Third the material transport. The means and methods of taking the packaging material after cutoff and getting it to a position ready to do its first primarily intended work. This work first begins at the point of contact during the actual packaging of the product. After the preliminary contact the packaging material goes through a variety of processes wherein it is shaped, formed, or folded into finished package style.

Fourth and fifth are concerned with packaging and enclosing the product.

Last and perhaps most important of all, since it results in the final quality and appearance of the package, is package sealing. This can be done in a great variety of ways.

Thirty-Four Check Factors

It should be mentioned here that in the analysis of the six-component areas 34 factors were found (see Table I). Their various interrelationships and considerations concerning specific packaging materials are quite involved and in themselves are separate studies.

Paper Feed

Let us now go back to the first, keeping in mind the other five component areas of flexible packaging material usage. As mentioned earlier, thinking in terms of common terminology, we would find in the paper feed seven different potential trouble points and check factors. These in the general sequence of importance and usage would be tensile, stretch, curl, block, caliper, stiffness, and tear resistance.

Cutoff Mechanism

In the second-component area of machine considerations we would include all of the first seven factors and add hardness, internal stickiness, mar resistance, resilience, static, cutting resistance and elongation return.

Material Transport

Once again, going along in order of machine sequence, concerning the transporting of the packaging material we would add to the list slide resistance. This would be the coefficient of friction between the material surfaces on various members in contact. In addition, concerned with material transporting we would also have to reconsider the originally stated curl, stiffness, mar resistance and static.

By now a mental picture may have developed of a specific packaging material and it would appear that only three or four factors mentioned are involved. It must be kept in mind that automatic packaging machinery is designed to handle a great universal variety of packaging materials. Therefore, all factors must be considered with each and every material.

Table I. Flexible Packaging Materials
Check Factors and Trouble Points

Paper feed
1. Tensile
2. Stretch
3. Curl
4. Block
5. Caliper
6. Stiffness
7. Tear resistance

Cutoff mechanism
1 to 7
8. Hardness
9. Internal stickiness
10. Mar resistance
11. Resilience
12. Static
13. Cutting resistance
14. Elongation return

Material transport
3-6-10-12
15. Slide resistance

Packaging product
16. Puncture resistance
17. Product slide resistance

Packaging formation
3-6-9-10-11-12-14-15-17
18. Crease resistance
19. Slip (on itself)
20. Scuff resistance

Package sealing
6-9-10-11-15-17-18-19-20
21. Heat shrink temp.
22. Heat distortion temp.
23. Heat delamination conditions
24. Heat resistance temp.
25. Heat seal temp. range
26. Heat slide resistance
27. Heated tensile strength
28. Heated shrink strength
29. Heated coating buildup
30. Heater release
31. Special heat effects
32. Cooling requirements
33. Solvent effects
34. Adhesive effects

Packaging Product

When we think in terms of packaging a product we would basically be concerned only with puncture resistance and product slide resistance. The product slide resistance generally is the coefficient of friction of the inside of the packaging material with the outside of the product. It is very important that this be considered in terms of actual production conditions, which on many products can vary considerably over laboratory test methods.

Packaging Formation

Concerned with the formation of the package are three additional factors and nine others originally stated which round out package formation to a "baker's dozen."

The three new ones are: crease resistance, slip on itself, and scuff resistance.

Once again we go back and take two of the Paper Feed factors, curl and stiffness; five of the Cutoff Mechanism factors, internal stickiness, mar resistance, resilience, static and elongation return. In addition one each from the Material Transport and Packaging Product components, slide resistance and product slide resistance.

Package Sealing

In package sealing the greatest number of factors are involved. Considering all the basic packaging materials and the three basic styles of machines at the same time we would need to add 14 new factors to the nine previously mentioned. This represents two thirds of all the factors described.

The new factors are mainly concerned with the possible use of heat. Heat in most instances is used as a package sealing ally because of speed and low cost advantages. It also has a

great deal to do with minimizing the physical size of the packaging equipment. These heat factors are shrink and distortion temperatures, delamination conditions, resistance temperature, seal temperature range, slide resistance, heated tensile and shrink strengths, heated coating buildup, heater release, special heat effects, cooling requirements, solvent effect, adhesive effects. Again as described in packaging formation we find practically all of the same factors involved in Package Sealing. The exceptions to this would be curl, static, and elongation return.

MACHINE DESIGN CONSIDERATIONS

We have now, in effect, disected automatic packaging equipment in general terms. These can be used as a guide in setting up specifications for and analyzing trouble with flexible packaging materials.

Everyone probably understands it but it should be repeated. The specifications set up for packaging materials from a strictly package viewpoint do not necessarily coincide with the specifications for good machine operation. Like industry generally, the passing of time has developed requirements which have a tendency to build one on another. Forty-odd years ago, with the origination of some of the first automatic equipment, the machines were designed to handle the then existing paper. Reasonably good operation was expected using the lowest quality standards of the paper. From then on both the machines and the paper and the various paper substitutions have improved in quality. With this improvement in manufacturing standards each helps the other to do a better job at higher speeds.

Let us now look at a problem with which a machine designer has to contend. Visualize yourself as the designer with a problem of originating a brand new high-speed machine. You must use all the available knowledge and background experience at your command. In this case, let us say it is for frozen food wrapping. Typical, then, of the wrapper to be used would be a simple, printed, waxed sulfite sheet. One of the relatively simple problems the designer would meet would be in the very first part—the paper feed. The first factor listed here is tensile. The designer then asks a question of himself and seeks the answer. What is the average minimum tensile strength expected of a typical frozen food wrapper?

Either you or the people assisting you go out into industry by way of telephone expecting to find a simple answer to this question. The answer undoubtedly exists but you will not find it easily in any periodical or book. Nor to your own surprise will you find it easily by calling members of the industry directly associated with the manufacture and sale of frozen food wrappers. About the only way you would actually find this is to set up your own test for determinations. This should not be taken as criticism on parts of the paper industry. It obviously is a case of short term need for specific information, and like many other bits of information, are not always readily available. All that the engineer wanted to know originally was what his minimums were that he had to work with so that, in turn, stresses within his machine design could be planned on, including the factor of safety which would allow for good machine operation under normal production conditions without a web break.

As automatic equipment speed is increased several factors mentioned earlier tend to show up as severe trouble points. Associated with this subject I would like to mention at this time that except for extra special developments I have never heard of a papermaker going to a machine designer and working out the most economical sheet for a job. By *economical* is not meant just the cost of manufacturing the sheet; but more, the additional costs involved in automatic machine operation that can occur particularly where a new packaging material combination, because of one or more specific advantages, is being substituted for the original successfully operated sheet.

FIFTEEN UNCONTROLLED FACTORS

It is not the intention of this talk and paper to go into specific details and fully analyze all the interaction and interrelationships between these 34 check factors, but rather to show their simple existence and lay out a road map, so to speak, so that others who follow will have a basis to work on. It has been estimated that of the 34, approximately 19 are things which are under normal quality control regulations and testing methods. Whereas the other 15 have been left in the lap of the machine manufacturer and machine user. There are very good reasons that this should be this way in the past, where the supplier and the supplier's supplier's main interest is selling materials. These 15 are curl, stiffness, hardness, internal stickiness, mar resistance, resilience, cutting resistance, heat delamination conditions, and slide resistance, heated coating buildup, heater release and special heat effects, and finally adhesive effects. It is not meant here to leave the impression that these 15 factors cannot be, or are not, tested for. The important thought is that these factors are the source of trouble under certain conditions in packaging programs. The problems arise from lack of understanding, foresight, analysis, and the urgency of doing business.

The packaging market is continually changing. There simply is not time enough to do much more than trial-and-error type of testing to determine just what is best for machine operation. This does not have to be so.

It can easily be seen of the previously listed factors some are much more important than others in certain obvious instances. For example, stiffness, if a packaging material stiffness is sufficient, at least in overwrapping machines, it can overcome and eliminate the need for consideration of one or more of the other factors. In this instance they would probably be in the area of slide and slip or coefficient of frictions; wherein what is known as drag-back would be eliminated. Drag-back occurs where various fold formers and tucking mechanisms have a tendency, because of frictional characteristics or otherwise, to defeat the mechanism's intended purpose.

The aim of this listing of the 34 factors is to point up the fact that they do exist, can be analyzed and determinations made and information correlated in such a manner that the successful operation of a packaging material can be predicted in advance of its manufacture to a much greater degree than present methods. It might be assumed that it is necessary to check and correlate all the interlocking factors because each is related to the other. This would give 34^2 in number, and to think on a thousand different considerations would be an impossible task. It is necessary though that the people involved with the responsibility for machine design and manufacture and the packaging material supplier, in conjunction with the converter, understand as much as possible and follow through as far as they can in their own area of responsibility to see that the best material is produced and the most economical and efficient packaging line results.

CONCLUSION

I believe there is in existence available knowledge, in several different areas, that can be combined in a satisfactory manner in terms of the 34 factors mentioned, which would allow for a much better understanding and a greater efficiency in the production of flexible packaging materials for automatic packaging. To accomplish the objective requires considerable interindustry cooperation. This naturally is a slow and gradual process. It is not and cannot be expected that all those who supply the equipment and materials to packaging lines within a company have interlocking or overlapping responsibilities, at the present time. There is an area between each supplier that must be filled with knowledge and responsibility by someone. Any that are not taken care of by the supplier must of necessity be accomplished by the packaging line management. As the years roll by and the packaging

industry matures these areas of loose responsibility will normally be eliminated a step at a time. As the segments of industry involved standardize, some system will have to be set up which includes complete responsibility. It is only logical that all of these details from the technical angle would be worked out and full interlocking information be available within the suppliers themselves, so the packaging line operators can spend their time and energies on the basic things of their manufacture and not be used as day-to-day trouble shooters for somebody elses responsibility.

Received Sept. 16, 1959. Presented at the Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, held in Chicago, Ill., Sept. 20–23, 1959.

The Problem of Odor in Polyethylene-Coated Structures

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Odor in extrusion coated polyethylene is an insidious characteristic which must be controlled in order that polyethylene-coated materials may enjoy a continuing growth in the packaging of food products. The adjective *insidious* was used because Webster's definition is "working ill by slow and stealthy means." This, we felt was an apt description because a few odor seeds, planted unwittingly, can, by feeding upon themselves, slowly grow into an unwanted weed field.

Having recognized this treacherous behavior we launched an extensive study into the factors responsible for odor development with their control being our ultimate goal. This paper describes the steps taken toward that goal which, although not completely realized, is much closer in view.

The first step in the program consisted in obtaining films having varying degrees of odor in order that our test method for odor determination could be critically examined for reproducibility and sensitivity. The method consists of containing a sample of given size in a Mason jar, storing the jar at 120°F. for 30 min., cooling jar and contents, and finally sniffing the contents. A panel of five individuals, chosen for high sensitivity in odor detection, rates the odor on a scale from 0 to 10, where 10 represents no detectable odor.

Films were produced on a $3^1/_4$-in. extruder using dwell times of 3 and 9 min. at melt temperatures of 400 and 600°F. Dwell was determined by measuring the time required for a colored pellet of polyethylene, dropped in the throat of the screw, to produce color in the extruded film. The melt temperature was measured by an immersion thermocouple in the channel between the end of the barrel and the die. These samples were evaluated for odor according to the above described test method. The results, listed in Table I, indicated that a significant difference in odor was noted only in the high temperature-long dwell sample (sample 4) with a rating of 8 compared to 9 for the other three. This was a disappointingly small difference in view of the extremes in extrusion conditions under which the samples were prepared.

Suspecting that odor was caused by an oxidative process evolving aldehydes, ketones and fatty acids, these samples were analyzed for carbonyl content by infrared absorption using a Perkins Elmer Infracord. The characteristic carbonyl absorption peak at 5.8 μ wavelength was noticeable, but only in sample 4 (see Table I). This result was both heartening and disappointing for though it confirmed that carbonyl groups were present in the most odoriferous sample, it had been hoped that a gradation in carbonyl content would be observed, corresponding to the degree of heat damage to the samples.

To accentuate the odor, and, hopefully, the carbonyl content, the same set of samples was exposed to a temperature of 200°F. for varying lengths of time. As can be seen from Table II, progressive odor development, as detected by sniffing, occurred but only in sample 4, the film extruded at a temperature normal to extrusion coating but with a long residence time.

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Table I. Effect of Extrusion Conditions on Odor and Carbonyl Content

Sample no.	*Extrusion conditions*		*Odor*[a]	*Presence of carbonyl*
	Temp., °F.	*Dwell, min.*		
1	400	3	9	No
2	400	9	9	No
3	600	3	9	No
4	600	9	8	Yes

[a] Arbitrary rating scale, 0–10, where 10 denotes no odor.

It will appear, upon examining the data in Table II, as though there has been a reduction in odor after an 8-hr. exposure of samples 2 and 3; for the rating has improved from 7 to 8. This phenomena is due to unreliability of the test method and is, in fact, the reason for retaining only one significant figure in the averaged results.

Infrared analyses were again conducted on these samples, and again the only sample with evident carbonyl content was sample 4. You will observe from Fig. 1 that the carbonyl peak is greatly accentuated as the oven exposure time is increased.

Thus the objective of the test had been fulfilled, for accelerated aging certainly produced a marked increase in odor and carbonyl content in the sample extruded at high temperature with long dwell. This suggests that the reliability of a sniff test for odor could be greatly improved by establishing exposure conditions of 24 hr. at 200°F.; for it does not require a sensitive nose to detect the difference in odor between ratings of 8 and 4.

In order to avoid interfering odors from the paper or other heat-sensitive substrate, coated samples must first be separated so that only the polyethylene ply is exposed. A more satisfactory technique for quality control is to extrude a short section of film with the combining nip open and the substrate web broken, all other conditions being identical to the production operation.

Table II. Polyethylene Odor Development After Exposure at 200°F.

Sample no.	*Exposure time, hr.*			
	4	*8*	*24*	*48*
1	8	8	8	8
2	7	8	8	7
3	7	8	8	8
4	7	6	4	3

Of greater importance, the results of these tests indicated that polyethylene which had not been severely heat damaged was relatively inert to objectionable odor development even on aging. Conversely, excessive heat damage will produce odor which, on accelerated aging, can become exceedingly objectionable. An explanation for this behavior probably lies in the complex oxidative reactions leading to odor development which, initiated in the extrusion operation, continue by autocatalysis.

Since these experiments confirmed that odor is the result of oxidative reactions caused by heat damage to the polymer, it would seem that prevention of odor could be simply achieved by avoiding high extrusion temperatures. This of course is true, but as the converter well knows, a high melt temperature is required to attain a necessary bond level to the substrate. Bonding to smooth substrates like aluminum foil, cellophane, and glassine requires the development of a polar surface on the polyethylene melt and adequate wetting of the substrate. Both of these factors requires a high melt temperature. Thus it is seen that the factors contributing to odor development are desirable, and in fact necessary, in order to secure firm bonds to substrates.

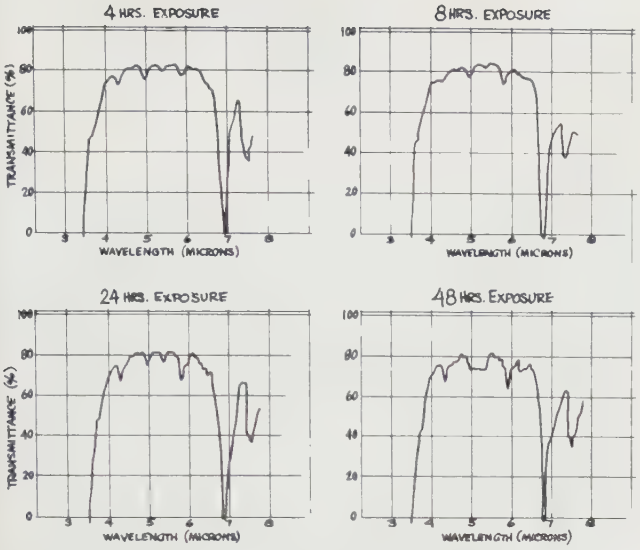

Fig. 1. Infrared absorption

Polyethylene sample 4 exposed at 200°F.

This situation has forced the extrusion coater to tread the familiar path of compromise. Too wide a deviation from this rather narrow path leads to trouble either on the boundaries of odor or bond.

Many attempts have been made to effect bond at reduced melt temperatures but with little success. Primers developed for this purpose have not been found significantly effectual. High melt index resins provide improved wetting at lower temperatures; and so they are particularly advantageous in relatively rough surfaced paper coating where the bond is developed by a mechanical interlocking with the paper fibers and does not require surface oxidation of the polyethylene.

Efforts have also been directed toward controlled surface oxidation of the extruded polyethylene. Union Carbide demonstrated that nitrogen-gas blanketing of the air gap prevented bonding of polyethylene to smooth substrates simply because it prevented the formation of polar oxidized groups necessary for electrochemical bonding. If the inert gas blanketing was restricted to the free, or unbonded, surface of the polyethylene, bonding was not hindered yet unwanted oxidation of the free surface was avoided. This led to improved heat-seal response and, presumably, better odor. Our own tests have borne out these conclusions; however we found that the effects of inert-gas blanketing were not lasting. Apparently there is sufficient oxidation within the mass of the polyethylene, from slight quantities of occluded air, to set off the chain reactions which eventually override the surface effect.

Another approach to controlled oxidation is the addition of antioxidant to the resin prior to extrusion. Experiments made by ourselves and others indicate that the formation of carbonyl groups is inhibited by antioxidant, but the ability to bond to smooth substrates is also inhibited by the absence of surface oxidation. The problem here, yet unresolved, is to determine if a practical range of antioxidant concentration exists wherein bonding is unaffected but odor is markedly improved. One might think that this could be answered quickly by a few well-directed experiments; however, there is a complicating factor in the volatility of di-*t*-butyl-*p*-cresol, in our knowledge the only suitable antioxidant from the standpoint of toxicity and color stability. Because of this volatility factor, residual concentrations are dependent not only on the amount incorporated in the polyethylene resin, but also on compound temperature and time of exposure in the air gap.

To those primarily interested in the extrusion coating of paper, where oxidative bonding is not involved, the use of antioxidant may provide a ready answer to odor problems.

From these findings it is evident that if objectionable odor is to be avoided, heat damage of polyethylene must be avoided. The only proven technique for accomplishing this is to maintain minimum extrusion temperature and dwell time, commensurate with achieving bond to the substrate. Other techniques, which demand further exploration, include inert-gas blanketing of the air gap, and controlled addition of antioxidant to the polyethylene resin.

Received Sept. 16, 1959. Presented at the 14th Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, held in Chicago, Ill., Sept. 20–23, 1959.

Proper Marriage of Paper to Plastics and Foils

YALE M. BRANDT

The use of glassine-foil-polyethylene combinations for flexible packaging is increasing. Reverse printing of transparent glassines overcomes many of the problems encountered with inks and coatings on the outside surface. Urea-sodium nitrate plasticizers in glassines adversely affect the rotogravure-applied nitrocellulose inks. Urea-glycol and urea-glycol-sugar plasticized papers are found to give satisfactory ink adhesion. Primer coatings, such as shellac, will also promote ink adhesion. A simple procedure for laboratory testing is described.

Specifically, the marriage of plasticized glassines, foil, and polyethylene will be reviewed. The major difficulty encountered with this specification, our approach to it, and the solutions we have worked out, will be outlined.

In the way of background, we are all aware of the rapid changes taking place daily in the packaging field. The trend is toward faster, more efficient packaging lines. New products are being developed that require far better protection than many in the past. Mr. and Mrs. Consumer are demanding more convenience in the products that they purchase from the market shelf. These trends have stimulated the development of new packaging machines and materials.

One of the most prominent developments has been in the increased use of pouches. Today, almost anything can be purchased in a pouch. Pouch packaging satisfies many of the demands of the producer and consumer by its ability to (1) be adapted to web-fed, higher speed packaging equipment, (2) offer excellent moisture and gas protection, (3) be printed in very attractive designs, and (4) promote the product's convenient use.

Generally, the pouch specification must form and drape "comfortably" around the product. It must offer good resistance to puncture and tear, give adequate potection, and should machine well. Essentially, the specification should be a flexible, impervious material with rapid sealing properties. The combination of printed film or paper, foil, and polyethylene provide the desired properties. The film or paper serves as the printing substrate and, along with the polyethylene, gives the specification its desired physical properties. The foil serves as the impervious barrier and also to increase the attractiveness of the printed design when it is allowed to show through. The polyethylene contributes strength and serves as the sealing medium.

The use of plastic films, such as cellophane or acetate, is common; and very attractive and functional materials can be produced. However, the films are relatively expensive, and so the use of plasticized glassines in place of the plastic films is growing. This may cause some sacrifice in the gloss and integrity of the design where reverse printing is used. The presence of nontransparentized fibers and shade variation can be a problem, and close control is required by the paper supplier to keep these factors in line.

Direct printing of white, opaque pouch papers has also

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Table I. Nitrocellulose Ink Adhesion
Characteristics to Various Plasticized Glassines

Per cent	*Plasticizer*
	SATISFACTORY INK BOND
7.0	Urea
11.0	Urea
15.0	Urea
11.0	Urea-glycol
12.0	Urea-glycol
15.0	Urea-glycol
7.5	Urea-glycol-sugar
11.0	Urea-glycol-sugar
	UNSATISFACTORY INK BOND
7.0	Urea-sodium nitrate
10.5	Urea-sodium nitrate
13.0	Urea-sodium nitrate
15.0	Urea-sodium nitrate
2.5	Invert. sugar

proved satisfactory. In these cases, it is usually necessary to furnish a protective overcoat for the inks. Scuffing, flaking, bleeding, and color stability in the heat-seal areas can be a problem. The use of a reverse-printed design offers an easy way to eliminate them as hazards.

The major difficulty that we experienced in the production of the reverse-printed glassine-foil-polyethylene specification was in obtaining a consistent paper-to-ink adhesion. The rotogravure nitrocellulose inks are found to have variable adhesion properties to the transparent plasticized glassines. The problem was first called to our attention when a comment was received that a newly designed package lacked color stability in the heat-seal area. The first reaction to this comment was to look at the heat resistance of the ink. However, when packages showing the defect were examined, it was apparent that the difficulty lay in the nitrocellulose ink adhesion to the paper. The contortion of the stock under serrated heat-seal jaws caused separation of the ink from the paper, and a marked change in the ink color, as viewed through the glassine.

The problem was taken up with our transparent glassine suppliers. The paper being used was essentially a no. 1 envelope window glassine, containing 12% plasticizer. Urea nitrate was generally used as the plasticizer, although it was common mill practice to use plasticizer remaining from the previous run as long as the paper produced met transparency and flexibility requirements. This variability in the basic components of the sheet was believed to be responsible for the variations in ink adhesion that had been reported. In order to determine which of the several commonly used plasticizers would give the best ink adhesion characteristics, a laboratory screening of samples was made.

PROCEDURE AND RESULTS

Sample sheets containing various quantities and types of plasticizer formulations were obtained from various suppliers of transparent glassines. A drawdown of a standard nitrocellulose ink was made on the sample sheet, using a no. 6 Mayer bar. The ink was then dried by laying the sheet on a hot plate (250°F.) until the solvent was driven off. The sheets were checked for tack and solvent odor before testing.

Ink adhesion was checked by the Scotch tape method.

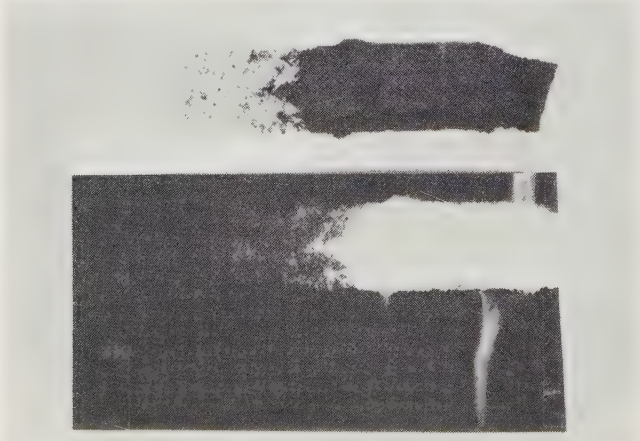

Fig. 1. Satisfactory nitrocellulose ink/glassine bond

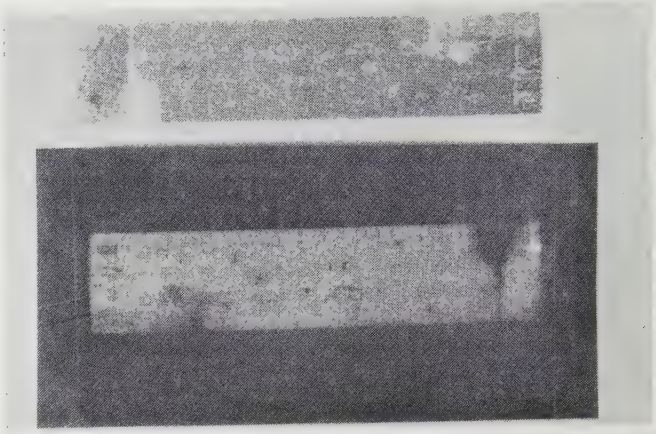

Fig. 2. Unsatisfactory nitrocellulose ink/glassine bond

Some of the sheets gave almost perfect release of the inks from the surface using this test. A fiber tearing bond was considered necessary to rate the sheet as satisfactory. Table I shows the variety of sheets tested and their rating. Figures 1 and 2 show the difference between satisfactory and unsatisfactory adhesion obtained with this test. As seen in Table I, urea, urea-glycol, and urea-glycol-sugar containing sheets were all rated as satisfactory. Urea-nitrate plasticized sheets were found to act as almost perfect release papers for the rotogravure nitrocellulose inks.

Application of the information gathered in the producing plants has worked out very well. Volume press runs on papers plasticized with both 12 and 15% urea-glycol and urea-glycol-sugar have been made, with excellent nitrocellulose ink adhesion. Testing these finished materials after 6 weeks' storage in hot-wet (100°F., 85% R. H.) and hot-dry (100°F., 25% R.H.) conditions have found the ink adhesion characteristics to remain satisfactory.

Specifying the plasticizer used in the glassine has been one of the ways we have eliminated a troublesome condition in a volume produced item. However, if the job were small or there were not time to secure a special run of glassine, an alternative method of improving nitrocellulose ink adhesion to plasticized glassines is available. This is to prime the glassine. We have found that a primer coat of shellac at less than 0.5 lb. per ream (24×36—500) is effective. Satisfactory ink adhesion characteristics were obtained using a primer on the urea-nitrate plasticized sheet. In addition to shellac, primers are available from several ink manufacturers that give excellent bond.

CONCLUSIONS

At the moment, we do not know why nitrocellulose ink has a selective affinity for certain plasticizers. The fact that it does has been easily demonstrated in both laboratory and plant.

Application of this phenomenon has made it possible to produce superior specifications without resorting to the use of an additional coating.

Since this type of flexible specification meets many of the demands of both the packager and the consumer, we feel that its use will continue to grow. With the proper selection of the component materials, production of this type of specification becomes routine.

RECEIVED Sept. 25, 1959. Presented at the 14th Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, held in Chicago, Ill., Sept. 21–23, 1959.

Rice Straw and Rye Straw for Pulp and Paper

THEODOR HÖPNER

THE West European countries are not the only ones which live in want of papermaking wood, and where recourse is had to other kinds of raw materials these will always, in the first place, enter into question, which as agricultural by- and waste products are, at any rate, already subjected to a recollecting and harvesting process. Since, according to a statistical information, one third of mankind lives on rice, there can be no doubt that in the future development of the paper industry special importance will be attributed to rice.

It is true that several straw pulp mills, besides other kinds of straw, also work up rice, and there are two smaller mills on Java which produce on the rice straw basis only, the one since 1920 and the other since 1940. These two mills, however, work under such peculiar conditions, as will be shown later, that not all the full extent of the problems involving this raw material becomes apparent. Despite all laboratory research work, calculations, and experimental productions which have been made public during the last years, there are still very interesting problems in this field, which are well worth discussion and reporting.

The digestion and preparatory processes will inevitably be adapted to those which in the straw pulp industry in general, with the processing of wheat and rye straw, have proved to be good—making use of all technical innovations, of course. As stated previously, development set in at various places; but today it is entering a new phase, owing to the striving for economical independence among the so-called underdeveloped peoples, because it is just those people who mostly live on rice.

What makes the processing of the annual plants more difficult, compared with wood, is the fact that they comprise a variety of different sorts, that they are largely sensitive to the influence of soil and climate, and above all, the inhomogeneity of each single plant which, unlike a tree, is used in the pulping process much more as a whole, making all efforts, of course, to eliminate already at the beginning all the less valuable parts. The much more extensive surface, compared with a tree, entails a bigger amount of adherent dirt, which for the production of pulp has to be removed.

A series of investigations with rice straw gave an average of 38% of the valuable internodes, 7% of knots, 53% of leaves and sheaths, besides panicles, spelts, and awns. With a larger number of rye plants, there was found an average of 66% internodes, 7% knots, 9% leaves, and 18% sheaths. At the sight of the camps, too, one does not doubt about the correctness of these statements. The rye-stalks are more than double as long and the ears are free, while the panicles of rice are surpassed to a large extent by the upper leaf, and the leaves themselves measure up to 60 cm. in length. According to (*1*) (EuCePa-Symposium, June, 1959) rye contains 61.5–65.6% of internodes and 20.7 to 24.3% of leaves and sheaths.

Besides the furfural number, which, in accordance with the literature we determined on both these cereals to about 18%*, on an ash-free basis, there remains among the analytical data only the ash which is of interest to us—and this ash is interesting to a very high degree. Here also we will only be quoting the average figures of the many determinations we carried out on various materials, and concerning the literature we confine ourselves to the statement that it is not contradictory to our results. We adduce three figures representing the oxide ash, sulfate ash, and the silicic ash:

Rye	3.8	4.9	1.1
Rice	18.2	19.0	13.0

The exceedingly high ash content of the rice straw requires careful consideration, both theoretically and practically. Because of the important part that the ash and the silicic acid play here, several different methods of determinations were compared without finding any serious differences. More critical is the problem of an even distribution, above all in washed (wet cleaned) straw. The ash is noticeably increasing in the plant from the upper part downwards.

Rice straw has not only by nature a higher content of leaves and sheaths, which are of inferior value for the production of pulp, but it is also more contaminated as a consequence of the growing conditions. As a well-known factor enters here the cross section of the stem (see Fig. X and XI), which with rye shows longitudinal streaks, with rice, however, marked small furrows in which dust and dirt settle down. So, if with the straw of our cereals a thorough dry cleaning is already advisable, the best thing for rice straw is a real prewashing in the pulper. Thus the ash content is notably reduced. If such a washing is carried out with rye, there will be obtained: unwashed, 4.0–4.9–1.2%; and washed, 2.7–3.1–0.8%.

A washing experiment typical of rice resulted in the fact that during the first quarter of an hour the oxide ash dropped from about 19 to 13%, the silicic acid from 13 to 12%, and moreover, the decrease after 3 hrs. was still 1%. The washing loss (50 = mesh sieve), for example, came to 11% with rye and to 25 to 30% with rice, also a consequence of the higher content of leaves. This loss covers, of course, also water-soluble substances. The total amount of hot-water extract was determined with a bigger quantity of rice straw, to 15.2%, with rye straw to 13.1%; in both cases, however, 40% being inorganic matter. A still further reduction of the ash by chemical means was possible only with the help of hydrofluoric acid. This, however, most surely would have been uneconomical, all the more, since for the purpose of papermaking the ash is not just detrimental.

Of vital importance is the fact that working with rice straw, all results must be re-calculated into ash-free substance (both straw and pulp), because otherwise a theoretical, completely wrong picture will be obtained. Practically, however, it must be calculated inclusive of ash.

Furthermore, the heterogeneous physical behavior of the two kinds of cereals in the washing has to be pointed out; the rye straw largely retains its shape, while the rice straw is largely transformed into fringes, naturally not as far as to the single fiber. This already suggests that digestion is easier with rice straw.

Under the microscope straw pulp always offers a rather complex picture. Bast cells, parenchyma, vessels, epithelial cells, present themselves here in a variety of forms and it is very troublesome and only possible—if at all—to distinguish a single kind among a mixture of several kinds of cereals in the pulp with the help of the surface cells. A comparative fractionation, which we carried out by means of the Bauer-McNett classifier with pulp from rice straw, rye straw, and beech wood, will probably give a certain insight into the characteristics of this material (processing without losses of fines).

The figures for the straw pulps are all re-calculated on ash-free. The ash content of the fines has not been determined by experiment but by calculation (Table I).

Table I. Fractionation of Pulps

Screen wires per in.	*Rice, %*	*Rye, %*	*Beech, %*
65	46.3	47.8	52.7
100	8.0	8.0	13.6
150	5.3	9.8	9.3
200	8.4	12.6	2.8
Fines	31.9	21.8	21.6

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* Distillation with hydrobromic acid according to Jayme (*9*), and titration with bromide-bromate.

65×

150×

100×

200×

Figs. 1 to 4. Fractionation of rice-straw-pulp. Figures represent wires per inch

The figures move in the same direction but the difference in fines becomes clear enough. Of the first two fractions we made fiber-measurements with the rice straw, which delivered lengths of 0.4 to 3.2 mm., on an average 1.23 mm. According to the literature, there is no difference in the length of rice and rye fibers; however, according to Lathrop (*2*) there is a difference in diameter. Thus the ratio of length/diameter becomes much higher with rice than with rye (170 by 120) which is of great importance for sheet formation. And this assertion is really proved to be correct by every inspection under the microscope. However, we have not carried out thickness measurements.

Figures 1 to 5 show different fractions. Figure 1 contains practically only fibers of a high quality, in reality, however, grit is also present here (Fig. 9). In Fig. 2, there are also insufficiently disintegrated groups of epithelial and parenchyma cells as well as sections of vessels. These nonfibrous ingredients in a disintegrated condition prevail in the third and fourth fractions and predominate completely in the fines (Fig. 10 and 11).

The so-called grit consists of rags of epithelial and parenchyma aggregates, which, as we could prove, dispose of no properties favorable to sheet-formation, not even after having been beaten. It is a very great advantage that the Centri-Cleaner eliminates almost exclusively all these parts. From rye we only represent the first fraction and the fines.

The strongly linked epithelial cells are characteristics of all graminaceous plants and are, naturally, abundant in the leaves. Figures 6 and 7 show pulp from the leaves of the rice straw. Apart from the useless epithelial cells, they also show good fibers. Figure 8, pulp from rice husks, shows very interesting and extraordinarily long and linked epithelial cells. But the ingredients of inferior quality are so predominant here that pulp from rice husks is of absolutely no value. It is, moreover, much more difficult to digest the husks than the straw. We finally must remark that all epithelial cells are

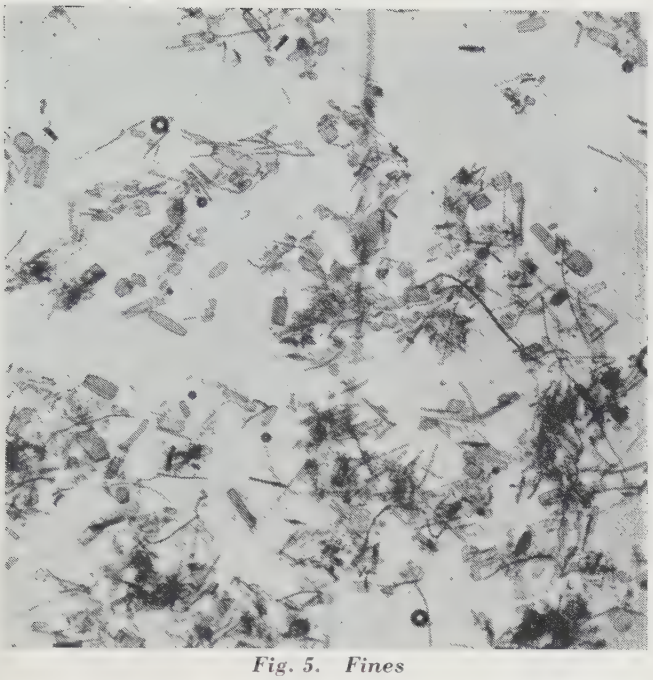


Fig. 5. Fines

very difficult to bleach, and that their elimination by means of the Centri-Cleaner signifies a considerable brightening up of the bleached pulp.

The acid sulfite method has proved—not only in our research work—not to be suitable for the digestion of straw, yet not just impossible. It is in the first place the soda process which enters into consideration. The addition of small amounts of sulfite and sulfide as well as carbonate is, as stated by us already on various occasions, at least of only very little effect, as far as the total alkali is not increased by it. The neutral sulfite process itself is, not in the least, a question of local conditions, and the ash problem is mostly disturbing.

Revolving autoclaves and tumbling digesters of a capacity ranging from 5 liters to 50 cu. m. were at our disposal for the digestion, as well as a pilot-pulper of the Voith type with a capacity of 50 liters. According to the method of Jayme, a 15-liter-digester was fitted with four insertion tubes of 1 liter each, destined for parallel cookings. It is very difficult to reach, with straw pulp, complete conformity between laboratory experiments and large-scale cookings, since in the latter case the high charge-weight has always also a mechanical effect during the rotation. And in the mill it is often very difficult to secure an equal distribution of chemicals and steam. The repeatedly observed after evaporations on the opening of an already released digester, which, as is known, have caused many regrettable accidents, prove that in spite of every care, there occur differences in temperature. Naturally, the continuous method has some advantages, but also its difficulties, which shall not be discussed on this occasion.

We have tried to examine all important variants of the cooking conditions.

LIQUOR RATIO

For reasons of steam economy technical production is interested in operating with a possibly small liquor volume, above all when black liquor is to be evaporated. The necessary degree of mixing is accomplished by the rotation of the charge-weight and by suitable devices fitted into the digester. We have carried out laboratory experiments with proportions of up to 2:1 and 1:1. The first proportion gave a pulp of still good quality, the second a still serviceable one. But it is difficult to guarantee with such a working method the necessary homogeneity.

For laboratory operations this also applies to the proportion of 3:1, which is common in large-scale operation (respectively 4:1 with condensate). The best effects were obtained with a proportion of 6:1, which allows the whole liquor just to be sucked up by the straw. Hereafter, there are no more difficulties in obtaining an even mixture before cooking. Bigger quantities of liquor seem to be of no direct disadvantage; they exact, however, a good continuous mixing, such as is given in the Aronowsky method. Incidentally, swelled straw could be pressed out again to a moisture freeness of 37%, without doing any harm to the fibers.

We made exact comparisons of the yields with liquor ratios of 6:1 and 4:1 and found that the latter one gave 1% more ash, calculated on a pulp basis. After re-calculation on ash-free straw and ash-free pulp, there remained a maximum difference of 0.5%, which is too near to the error limit. Concerning the strength values, there could be stated at most that the bigger volume of liquor was somewhat favorable with regard to the folding endurance.

PROCESSING

Here also on a laboratory basis the procedure must be slightly different than with wood, since the mechanical refining often causes an alteration of the beating degree, and with screening, the content of fines, and consequently also that of ash, and the degree of pulping are changed.

The Shopper-type defibrator must not be allowed with rice straw pulp to run at a higher speed than 1500 r.p.m. unless a very considerable beating effect results. With rye, this seems to be of less importance.

EFFECT OF PRELIMINARY CLEANING

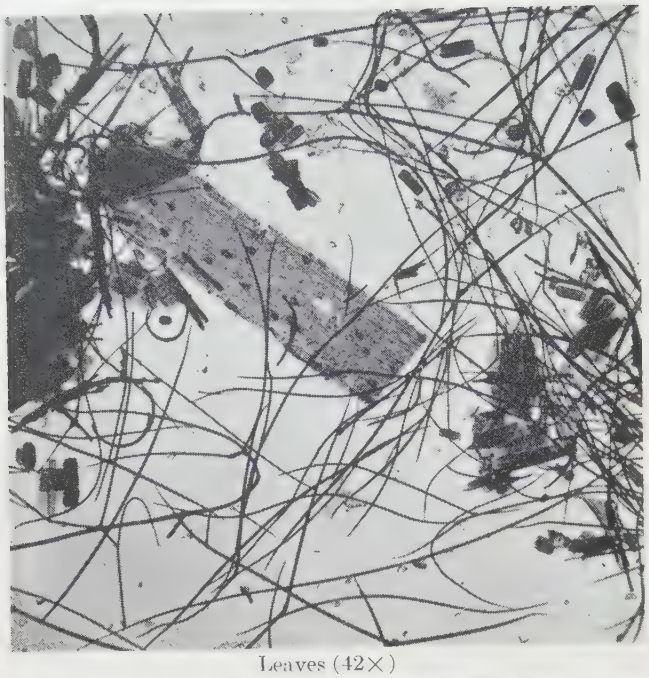
It has already been stated above that preliminary cleaning is of essential importance with rice straw in order to reach a good purity of the paper. "Cleaned straw" is no fixed specification, and it is really not possible to determine any precise end point of a cleaning. The ideal case would be a material consisting only of the internodes, free from all adherent dust, without leaves or sheaths. It is absolutely uneconomical to elaborate such material if it does not result by itself under appropriate harvesting circumstances. This is really the case in Indonesia. Furthermore, only approximately the upper third of the halm is used, which is especially advantageous. Such material needs no preliminary cleaning. We will refer to it later.

The case is quite different if, as in countries with an especially dry climate, the whole of the straw is harvested and, moreover, there are no purifying rainfalls during the harvesting season. The difference between washed and unwashed straw then becomes preponderantly apparent in the output, having a higher content of fines, that is to say a greater amount of loss during the preparation of unwashed straw.

As we will see, it can be easily calculated that the unwashed material unnecessarily consumes about 10% more NaOH, where surely the water-soluble substance plays its part. Apart from this, there has also to be considered the influence that unwashed material holds upon the purity of the pulp. As far as the washing wastes from rice straw could be retained by a 1200-mesh sieve, a pulp was still produced from it which, in the yield, did not differ greatly from the unwashed straw; however, it had a very low D.P. (744) and delivered very bad strength values (folding endurance 0 and so forth). Consequently, with this material there is nothing lost. Fiber fractionations, on all counts, proved a decrease of fines with an incresing washing. The washed straw in most cases was carefully re-dried for the cooking in order to obtain exact weights. However, to be on the safe side, we also digested directly in the wet condition, after drying even at 110°C. and finally overnight, after having macerated it again in the cooking liquor. The differences in the results were so low that we cannot speak of any influence here.

Influence of the Amount of Chemicals

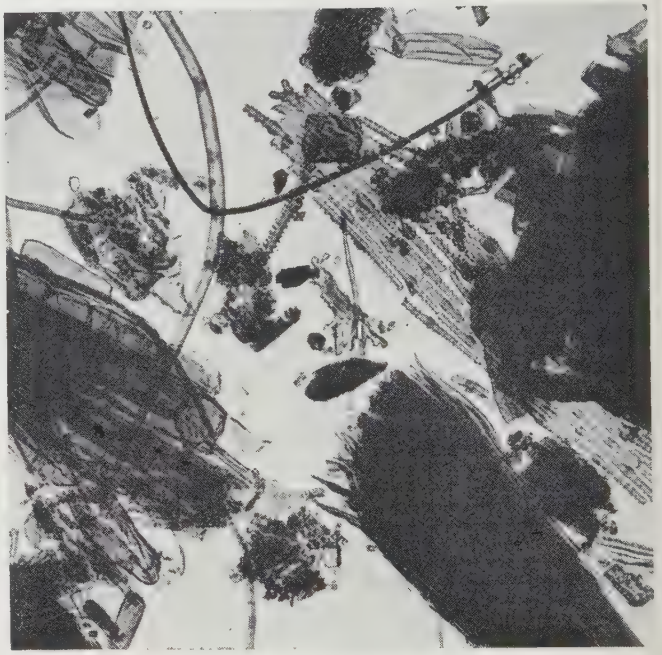
The fact that with straw there is no sharp limit between



Leaves (42×)

Leaves (120×)

Husks (42×)



Rejects from Centri-Cleaner grit (120×)

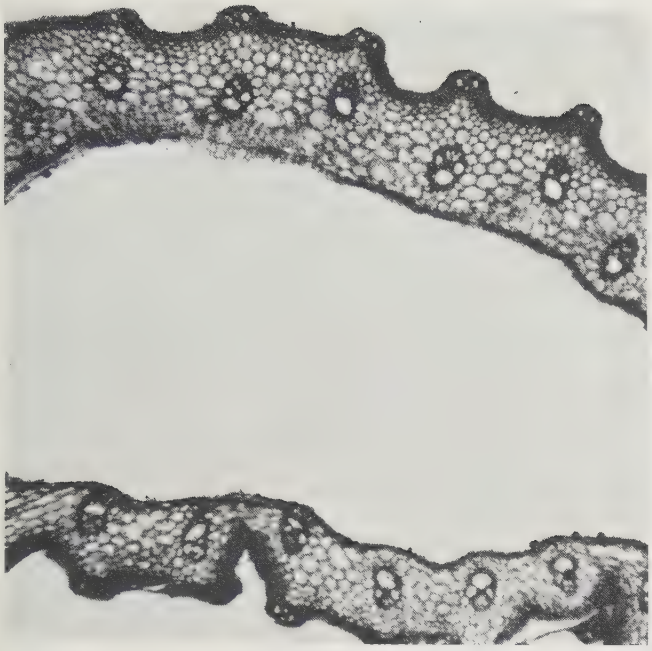
Figs. 6 to 9. Rice straw; pulp from leaves and husks

semichemical pulp and chemical pulp as well as the interdependency of ash and alkali, and furthermore, the inhomogeneous behavior of the various halm sections and the great influence of the pulp and liquor movement makes it rather difficult to make any definite statements on this issue.

With such small quantities as $8^1/_2\%$ NaOH, calculated on ash-free straw, it is already possible to produce a pulp, although the strength properties of it are not so good because the ash content is very high and its defibration is a bit difficult. Here the quality of the straw plays an important part.

A really good pulp normally requires considerably more alkali, namely, 13 to 15%, on an ash-free basis (11 to 13% from the raw material). At a temperature of 120 to 130°C. about 3% regularly remains unconsumed so far that they can be back-titrated to a pH of 8.3.

If the amount of chemicals added is too small it is more thoroughly consumed, and the consumption is still less, on the other hand, if the amount is bigger; but the remainder of about 3%, which corresponds approximately a 0.1 *N* NaOH lye, constantly turned up in our series of experiments and covered a strikingly large range of varying operation conditions. Soda (carbonate) is not contained in our remainder, because the sample of black liquor was always precipitated with $BaCl_2$ before titration. It is not advisable to enforce the consumption of this remainder by either high cooking temperature or prolonged cooking time, because of the silicic acid which would precipitate from the solution (*3, 4*). We at least found that at more elevated temperatures the ash was notably higher than at lower temperature, and that it dropped considerably with increasing amount of added alkali. The remainder can be largely utilized, however, by re-application of the black liquor. The problem of recovering the black liquor will be treated later. Higher amounts of alkali added entail higher consumption and further decrease of silicic acid in the pulp. Against damages, rice straw cellulose proves to be remarkably resistant, as the constant behavior of the degree of polymerization demonstrated (Table II).



Rice

Rye

Figs. 10 and 11. Cross section of the stems of rice and rye

In the unbleached condition, there is a difference in the yield of 5% on straw, between 8.4 and 19.3% at both 170 and 128°C., whereas in the bleached condition it is only 2% at 170°C., and at 128°C., there is no difference at all. With regard to the D.P., there are practically no differences.

The fact that the results of a thorough preliminary cleaning treatment of the straw significantly economizes alkali has already been mentioned.

Cooking Temperature

Continuing to draw our conclusions from this same table, we state that with equal addition of alkali the ash was by 3 to 4% higher at 170°C. than at the lower temperature, which is fundamentally in concordance with the statements by Lauer and Gonheim (*4*), who explained this phenomenon already by re-precipitation of the silicic acid with increasing consumption of the alkali. The digestion degree, re-calculated on an ash-free basis, was hardly favored by the higher cooking temperature. The yield, however, was notably discouraging (5% and more from the straw, also in bleached condition). The consumption of alkali was approximately 2% higher at 170°C., the D.P. did not change (see Table II).

The strength is apparently lower at higher cooking temperatures; however, it is difficult to judge correctly the influence of the higher ash content in this connection. Also with equal ash content the higher cooking temperatures is not an advantage. A further dropping of the cooking temperature to as low as 105°C. resulted to an unimportant degree in the continuation of the tendencies observed between 170 and 130°C. Cookings at 100°C. have been successfully carried out already by Lauer and Gonheim (*4*), as well as recently by Fahmy (*5*). Whether such methods will prove to be practical in commercial production does not only depend upon the cooking steam. There is no doubt that somewhat higher cooking temperatures are not detrimental.

Effect of the Cooking Time

Here also applies the fact—the same as to temperature and alkali—that, at least when operating batchwise, it is not possible to confine it to lowest possible values, since the adjustment of both temperature and concentration requires on all account adequate time. Thus, also when working on a small-production level, the picture is veiled. The fundamental proportions become apparent from the following series of experiments which were carried out in four pressure tubes at a temperature of 130°C. with 14% NaOH from absolute dry straw. All figures have been re-calculated again on an ash-free basis.

This table suggests that a 30-min. cook was almost sufficient and that afterwards only very few alterations took place. In another case, a cooking time of 30 min. in the autoclave, and the amount of alkali added being reduced by 1%, was not sufficient and we had to repeat this cooking phase. Under these conditions, we shall have to count on 1-hr. cooking time. At any rate, we are experimenting here at a limit which is notably shifted by slight variations in the operating conditions. Also at 170°C. we had to realize that a prolonged cooking time at least was not advantageous for neither the degree of digestion nor the viscosity. At a temperature of 105°C., obviously an essentially longer cook-

Table II

	170°C., 2 hr.				*128°C., 2 hr.*			
Alkali, calcd. on ash-free straw, %	8.4	10.8	14.5	19.3	8.4	10.8	14.5	19.3
J-N number[a]	86	68	54	52	85	68	61	56
Ash, %	23	23	19	12.5	19	18	17	9.5
Yield, % ash-free on ash-free	64.0	62.0	60.6	58.8	70.9	67.1	67.0	64.7
Bleached yield, %	56.1	56.5	55.8	54.1	60.0	59.3	63.4	60.0

[a] Johnson-Noll permanganate no. FAK-Merkblatt 2. All re-calculated on ash-free substance.

Table III

	Cooking time min.,			
	30	*60*	*120*	*240*
Addition of NaOH, %	16.5	16.5	16.5	16.5
Consumption of NaOH, %	12.2	12.3	12.5	13.0
Yield, %	65.6	64.0	..	63.5
J-N number[a]	54	50	50	50
D.P.	1290	1320	1280	1300
Ash, %				
Oxide	5.6	5.3	5.3	5.6
Sulfate	8.3	8.5	9.0	8.5
SiO_2	2.2	1.9	1.6	0.7

[a] See Table II.

Table IV

	Rice		Rye	
	Unwashed	Washed	Unwashed	Washed
Number of experiments	5	52	9	7
% NaOH addition	14.4	14.2	15.6	14.8
Temperature, °C.	132	123	147	143
J-N number[a]	52	52.5	61	60
Yield, %	59.5	66.3	53.3	58.8

[a] Johnson-Noll Permanganate no.

ing time was required. With 15 to 16% NaOH (on ash-free straw basis), we had not quite reached the goal after 1 hr. in the revolving autoclave, but needed 2 hr. The resulting pulp possessed certain advantages. The fact that a prolonged cooking time after the almost complete consumption of the chemicals would have no advantageous influence seems to be self-evident.

THE YIELD

From Table II it is seen that a decrease of 5 to 6% accompanies an increasing addition of alkali, both at 170 and at 128°C., and gives about the same difference, between both temperatures and with the same amount of alkali added, while after bleaching the influence of temperature still makes up 3 to 6%. The influence of the alkali, however, vanished completely at the lower temperature and almost completely at the higher temperature.

We have already mentioned that well-washed straw gives considerably higher yields (up to 6% more from the straw, calculated ash-free on ash-free) than the unwashed. If all the other processing conditions are maintained we have, in general, only insignificant fluctuations in the yields, provided that no completely different kind of raw material is applied.

Table IV shows the following average figures (all calculated with ash corrections). Re-calculation on completely equal cooking conditions, which, however, is only of theoretical interest, gives a difference of about 5.5% with rice and 4% with rye on a straw basis. Direct parellel experiments confirm the result.

The ash correction which concerns both the Johnson-Noll number and the yield, consequently causes almost no change in the relative ratios concerning the washing effect. Furthermore, we have to state that, on the whole, washing is of an advantageous influence for the yield, especially notable with ash-free calculations. Rice straw gives notably higher total yields than rye straw (unbleached). However, if it is considered that with rice straw almost 30% of the raw material was eliminated before cooking, whereas with rye straw only about 10%, the picture obtained with regard to the straw charge turns out to be quite different.

The Indonesian material, on the other hand, resulted immediately, with no preliminary cleaning and an average J-N number of 52, in an average yield of 67%, ash-free on ash-free, a value, as can be seen, of a well-washed straw of other provenance. Thus it is without any question the most valuable material.

In order to prevent misunderstandings, we must point once again to the fact that commercial production must reckon with 15 to 20% of ash in the straw.

The ash in the pulp fluctuated in our experiments according to the amount of alkali added, the cooking temperature, and the intensity of the screening, between 23—24—21 and 3.3—6.3—0.7 and with Indonesian straw up to 2—3—0.4; the most essential item is the amount of alkali.

The degree of pulping is, in general, not a good distinction with the straw pulps cooked with alkali. Screening causes at times a dropping of the J-N number. Therefore, we cannot encounter a uniform interrelation between degree of pulping and yield throughout the whole of our work, this being possible, however, in separate series of experiments. The present series of experiments—Table II—would give 5 to 6 J-N number points on 1% of yield, which is the same number we obtain with spruce sulfite pulps. Rye always had about 10 points higher pulping degrees than rice.

Table V. Cooking Data

Average

Group	Number of cooks	NaOH, moisture-free straw basis, %	Max. temp., °C.	Time at max. temp., hr.	J-N number	Yield, %	Ash in pulp, %
I	8	12.3	124	2	50	66.5	4.7
II	6	13.0	125	2	54	64.1	11.2
III	6	10.0	130	2	61	67	17.0
IV	8	13.0	125	2	−/45		6.3

PHYSICAL PROPERTIES

Degree of Beating

It lies in the nature of things that just the non-beating degrees of slush pulps with a fast beating rate are strongly influenced by the method of defibration applied. Therefore, in order to obtain correct values, it is advisable to proceed very carefully. We found that the normal values lie around 30°S.-R. Higher values are a sign of an unintended beating effect, lower ones may be all right, however, may they as well be due to a content of coarse material, but most probably they are the consequence of a loss of fines during the processing of the material. The same material without mechanical defibration resulted in 33°S.-R., after 5 min. of treatment in the FAK defibrator in 43.5°S.-R., after dissolution in the kneading machine in 34.5°S.-R., and after spraying and dewatering under loss of fines in 30.5°S.-R. In order to make clear the effect of the defibrator, a further series of investigation was carried out with another pulp. The result at 3100 r.p.m. was 26.5°S.-R. after 1 min., 30°S.-R. after 3 min., 30°S.-R. after 5 min., and 38.5°S.-R. after 15 min. With the defibrator running at half that speed, however, 24.0°S.-R. was reached after 1 min. and 27°S.-R. after 5 min. Still another experiment gave the value of 21.5°S.-R. after coarse sorting. At a higher consistency in the defibrator, after 1 min. the value of 23.5°S.-R., after 5 min. 25.5°S.-R., after 15 min. 31°S.-R., and after 30 min. 36°S.-R., after cleaner treatment 34.5°S.-R., and after approximately 10% loss of fines during dewatering 24°S.-R. The material removed by the cleaner consisted mainly of grit which, as can easily be imagined, would make the sheet porous. In the following paragraph further proof will be furnished for the fact that the beating degree is raised by strong defibration and reduced by loss of fines.

Strength Properties†

There is hardly any other raw material like rice straw which presents so many difficulties in obtaining comparable figures. With unsorted material the actual properties are masked to a large extent by the ash which, however, cannot be eliminated without, at the same time, suffering losses of fines which, as we shall come to see later, affect the various strength properties of the paper in rather different ways, partly even in a most detrimental way. The content of

† Deutsche Einheitsmethoden.

Table VI. Strength Properties

Average of Beating Points Each

Group	Beating time, min.	Beating, degree °S.-R.	Breaking length, km.	Folding endurance	Bursting area, sq. m.	Tearing strength, g. cm./cm.
I	0—5—10—20	255	29.8	1885	157.1	373
II	"	275	27.4	1265	139.0	362
III	"	256	22.9	635	108.5	329
IV	"	189	27.7	3661	152.0	496

epidermis and parenchyma, constituting the grit in the cleaner, also seems to be of unfavorable influence. The non-beating degree values, moreover, are always changed with too strong an attack during the difibration. And finally, during sheet formation, there is always lost 1/3 of the ash and surely also some portion of the fines.

First, in order to clear up the influence of the ash, we divided material which definitely had suffered no losses of fines during the preparatory treatment into three groups, according to the ash content. To keep the number of figures at a minimum the four beating points were totaled each time. A fourth group covers material which suffered partial losses of grit and fines during the screening. So the low ash content here results from the screening and not from the cooking process (Tables V and VI).

In the groups I to III, the non-beating degree is always about 40. It seems that the disintegration caused already a certain increase in the degree of beating, and so it is of no interest here to quote the single NB values. Since on the other hand mechanical defibration is scarcely evitable, it seems that the natural NB values are only of theoretical interest. Of great importance, however, is the fact—clearly visible in Table VI—that in group IV all degrees of beating are nearly 1/3 lower than in groups I to III; this being the consequence of the loss of fines. The actual strength properties are still developing up to 20 min. of beating time, with the exception of the tearing strength which in most cases, with the second beating point at least, becomes retrograde. Further continuation of beating is out of question here because of the high degree of beating already reached and the strong dropping of the tearing strength. The influence of the ash becomes quite evident in Table V. From groups I to III there are no distinct differences in the degree of beating. The tensile breaking length and the bursting area decrease with increasing ash content by about 30%, the folding endurance by 65%, the tearing strength by about 12%.

The groups I and IV do not actually differ from each other by their ash content, this being almost equally high in both cases, but much more by the lower content of fines and grit in group IV. For the breaking length as well as for the bursting area this apparently seems to be a slight disadvantage, but the folding endurance has increased by 100% and the tearing strength by 30%. This group IV covers the best pulps, of course, which, however, had been obtained under considerable losses of the yield. The amount of these losses will be given by special experiments later.

We have tested the influence of the ash by means of another method consisting in adding varying quantities of kaolin to a pulp which previously had been reduced in ash by means of high losses of fines. In order to reach comparable figures, the ash has to be determined in the Rapid-sheets, in this case. As a matter of fact, the native ash most likely will be able to be compared with the added one only partially.

By comparing these figures to the values at 0 and 10 minutes of beating time in groups I to III, we found the following changes in the strength properties, with an increase of 5% of ash in the Rapid-sheets. Considering the difficult conditions, the ratios found can be regarded as quite satisfactory.

Table VII. Change of Characteristics on 5% Ash Difference

	Beating degree, %	*Tensile strength, %*	*Folding endurance, %*	*Bursting area, %*	*Tearing strength, %*
NB-Point					
Native ash	Not clear	−15	−40	−22	−10
Added ash	±0	−10	−30	−10	−15
10 min. beating					
Native ash	+2.5	−12	−45	−19	−12
Added ash	+3	−20	−40	−25	12

Last but not least, we have also tried to check in severa cases, with corresponding material, the changes of the strength properties during the cleaner treatment and drainage on the sieve, possibly under simultaneous determination of the respective losses. With regard to the fines, this proved to be very difficult just on a semitechnical scale of operation which is imposed by the dimension of the cleaner. Nevertheless we can say that at a loss of about 10% each (on pulp basis) in both stages—which for large-scale operation may be too high—the beating degree drops by about 15% on the whole, the breaking length by about 5%, the bursting area by about 12%, while the tearing strength increases by 25 to 30%, and the folding endurance by nearly 200%.

So the differences are rather larger than stated in the above-mentioned groups I and IV, which means that they fundamentally confirm the results found there. Our results, furthermore, clearly reveal that pulps which have been cooked at 170°C. behave, with regard to both the influence of screening and the absolute values of the strength properties, practically in the same way provided that trials to equate the ash content are successful.

Thus, it may well be maintained that a pulp of a good tearing strength and folding endurance is not produced in the digester but in the sorting process.

Finally, in order to give a good insight into the absolute values of the strength properties, we are still quoting separately the average values for the single beating points (pulps poor of ash, with and without screening losses) of the aforesaid groups.

For better clarification, the corresponding values of rye straw cookings are also included, where we do not need to distinguish between screened and unscreened. (The yield, however, must be omitted.) As has been already pointed out, the values given here are not top values but average ones.

FIBER FRACTIONATION

Fiber fractionation is the more important the more complex the cellular composition of the raw material. Therefore, it is more interesting with hardwood than with conifers, and with one-year plants the fractionation gives a better elucidation than does the degree of pulping. But apart from the raw material the fiber spectrum is depending here also upon the degree of dispersion and the content of fines. Treating the material in the aforesaid defibrator of 3000 r.p.m. at a consistency of 1.5% caused the beating degree at 30-min. beating, to rise from 23.5° to 36°S.-R. With the products at the different beating points we carried out fractionations by means of the Bauer-McNett classifier with sieves of 65, 100, 150, and 200 wires per in. With increasing degree of beating, the first fraction dropped by 8% on straw basis, whereas the fines increased by 6% of the pulp. The intermediate fractions changed much less.

It might well be that the increase of the degree of beating is due, in part, to a virtual beating effect and in part also to a crushing of fiber bundles; the fact, however, that what is lost in the first fraction appears in the fines proves that mostly no fibers are concerned here, and there is every indication that it is the grit, i.e., the aggregates of epithelial and parenchyma cells, which are disintegrated into small individual particles. In order to prove this supposition, the grit from the cleaner was also subjected to fractionation. The first fraction resulted in over 70%. Thus it seems to be a fact that in rice straw the fibers separate easier than the epithelium and parenchyma. And it seems that it is possible to remove these useless cells either as grit in the cleaner or in the form of fines on the dewatering sieve, depending upon the kind of mechanical treatment of the material. With rye it seems to be difficult because of the sharper cooking conditions.

Table VIII

No. of expts.	NaOH from ash-free, %	Temp., °C	Time, hr.	JN number, ash-free	Yield, %	Ash, %	Beating time, min.	Beating °S.-R.	Breaking length, km.	Folding endurance	Bursting area, sq. m.	Tearing strength, g.cm./cm.
					Group I: Unscreened							
7	14.3	124	2	50	66.5	4.7	0	41	6.1	220	33.5	103
							5	64	7.4	500	39.3	98
							10	71	7.8	570	41.0	92
							20	79	8.5	600	43.3	80
					Group IV: Screened							
8	15.8	125	2	45	..	4.0	0	28	6.1	580	33	120
							5	44	7.0	921	38	127
							10	51	7.2	960	40	126
							15	66	7.4	1200	41	123
							−20					
					Rye Straw Cookings							
3	15.5	150	2	58	..	2.4	0	33	8.6	660	46	112
							5	42	9.7	1050	51	108
							10–15	52	9.7	970	55	108
							15–20	60	9.7	940	56	104

In perfect agreement with this is the fact that the elimination of grit and fines affects mostly the strength properties in the same sense. The folding endurance and the tearing strength are clearly increasing in both cases.

In order to elucidate even more these relations we carried out fractionations with material from after the coarse screening (only loss of coarse material), after the cleaner treatment (loss of grit) and from the dewatering sieve (loss of fines).

An especially well-designed experiment produced the results in Table IX (with ash correction).

In the fines also accumulates the ash, which has already been eliminated in this calculation. Sample B shows a strong increase in fines, which is due, on the one hand, to reasons of calculation because of the decrease of the fraction I, and on the other hand, however, most probably also to the fact that the cleaner pump turns grit into fines. In C the conditions of A are approximately restored by losses of fines. The intermediate fractions change very little. The decrease of the degree of beating in C in connection with the loss of fines is also very impressive.

If the question is raised on what the fiber spectrum of rice straw pulp really looks like, it is necessary first of all, always to keep in mind and to stress that the picture is completely dependent on the point of processing from which the material has been taken. The most accurate spectrum would be that of a pulp which, apart from coarse material, had not yet suffered any losses, above all not of fines, but, in which the grit, that is to say the epithelial and parenchyma aggregates, has possibly already been converted into fines by means of effective refining, yet without having taken place already in it an actual beating effect. Grit contained in the first fraction falsely suggests too high a content of good fibers. In this sense we consider the following spectrum of a pulp with a degree of beating of 31°S.-R. to be characteristic. For comparison the spectrum of a beech KZ pulp after disintegration is also included.

Fraction: I, 45.6%; II, 8.1%; III, 12.5%; IV, 1.7%; fines, 31.9%.
Beech KZ pulp: I, 52.7%; II, 13.6%; III, 9.5%; IV, 2.8%; fines, 21.6%

Table IX. Changes in the Composition of Pulp at the Sorting

Material	A Coarse screening	B Cleaner treatment	C Dewatering sieve
Beating degree, °S.-R.	28.5	36.5	31.5
Fraction I (65 mesh)	47.5	40.9	45.8
Fraction II (100 mesh)	9.2	9.2	9.6
Fraction III (150 mesh)	9.2	10.9	10.6
Fraction IV (200 mesh)	3.5	4.0	4.6
Fraction V (fines)	30.4	35.3	29.3

DIGESTION AT ATMOSPHERIC PRESSURE

This method, propagated by Aronowsky (*6*) requires only very moderate conditions concerning temperature, cooking time, and alkali because here the digestion is supported by the mechanical effect of the pulper. In doing so the alkali is evenly distributed in all moments and especially in the zone of reaction there is maintained the highest possible concentration. Furthermore, the middle lamella is constantly being laid open and thus exposed to the action of the chemicals. Such digestion experiments have been carried out by us in the Voith type pilot pulper with a liquor ratio of 16:1 and 11.8% NaOH, calculated on ash-free straw for 1 hr. The 3.5% NaOH could be back-titrated to pH 8.3.

Owing to the small amount of alkali and the low temperature, the digestion degrees were rather high; but the material was defibered to a large extent and regarding the yield and the strength properties, it fitted completely into the framework of our best pressure cookings carried out at low temperature, whereby, however, unfortunately the beating effect of the pulper as well as losses of grit and fines had not yet been taken into account. The most outstanding item is the high non-beating degrees which, however, can be explained simply by a beating effect of the pulper. In practice such high degrees of beating have to be avoided. Also the high liquor ratio (10:1, according to Aronowsky) and the corresponding steam consumption are rather undesirable, and the energy applied is rather high.

The fact that at a temperature of 100°C., without moving the material, but with considerably more alkali (15.6% on a moisture-free basis), it is already possible to obtain a digestion, has been proved by Fahmy (*3*), but he still obtained some quite coarse material. In 2 hr. at 105°C. we obtained, with 13% moisture-free basis and without motion, an unobjectionable pulp If we wanted to make use of the advantages of the Aronowsky method also with rice straw, the danger exists that the dewatering may be badly affected.

VARIOUS KINDS OF STRAW

Three shipments of straw which we received from countries with dry climates gave under equal conditions practically the same ratio of degree of digestion and yield (average 66%, J-N number 53, at 120–130°C.) as well as similar strength data. The Indonesian rice straw showed a better behavior in every respect which, however, may be due to various reasons. Since only a rather limited amount of such material was available for us, we want to be careful in making any conclusions.

According to the literature a nonuniform behavior of rice straw of different provenance is also probable. In *Zellstoff und Papier*, pages 179–183 (1952), there are very interesting

Table X. Amount of NaOH and Ash Content

	a	*b*	*c*	*d*
Addition of *dry* NaOH, %	9.0	10.0	12.0	14.0
Pulping degree J-N no.	42	40	38	36
Dry yield, %	65.7	65.0	61.4	57.4
Ash, %	13.9	13.8	9.7	4.7
SiO_2, %	11.2	10.9	6.0	1.0
Calculated on straw				
SiO_2 in pulp, %	7.3	7.1	3.7	0.6
SiO_2 in black-liquor, %	3.75	2.3	5.4	11.1
Deficiency	2.1			1.5
	13.2			13.2

statements which, however, are difficult to compare with our results (7). Unscreened, we obtained ash values between 23 and 3% according to the conditions of experiment; with Indonesian straw, the corresponding value went down to 2%.

BLACK LIQUOR

For the manufacture of paper the high content of silicic acid of the rice straw basically does not constitute a problem; for the black liquor, however, it does, since its regeneration will be essentially impeded. There can be no doubt that there are means and ways of precipitating the silicic acid; but up to now they have not yet been tried on technical scale. Since the alkali consumption itself is not very high with rice straw it will be a question of the local conditions whether a regeneration should be introduced. At present we want only to point out that it is much in our hands whether the silicic acid after the cooking is contained in the pulp or in the black liquor. Table X shows the results obtained when straw containing 13.2% silicic acid was cooked for 2 hr. at 125°C. with varying amounts of alkali.

As can be seen in case *d*, 84% of the silicic acid was contained in the black liquor. This pulp, however, is by far the best one.

A special problem lies in the fact that at good digestions, with fair regularity, 3% NaOH from the straw, calculated on ash-free basis, remains unconsumed or bound to very low acids; this can be back-titrated to a pH of 8.3. We expressly made sure of the fact that after the addition of the calculated amount of fresh alkali, it is possible to cook, without damage, with 100% black liquor, making use of the remaining alkali. Already for the cooking with fresh cooking liquor it is rather easy to calculate that the digestion is partly not accomplished by NaOH but by silicates, since the basic material present in the straw is not sufficient for a neutralization of the silicic acid.

BLEACHING

Being an alkaline digestion, the color of the unbleached pulps is not bad. Since it was not planned to make any use of the pulp in this condition, we did not go further into this problem. It is clear that many factors are acting together here. However, we can state that the cooking from the washing rejects had a brightness degree of only 36.6%, unwashed and unscreened pulps 40% and a little higher, and on the other hand, the material which was best pre- and after-cleaned and had received a small amount of Na_2SO_3 had a brightness of 49%, so that it seems possible to consider the application of this unbleached pulp for newsprint.

On the whole, we want to shorten the discussion of the bleaching process. The cellulose from rice straw is not a very delicate material, and it is possible to reach in a single-stage treatment with favorable conditions a brightness of about 80%, provided that one is ready to put up with a certain decomposition. The one-stage bleaching, however, might be the reason for the decrease in quality in technical bleaching which was stated by Jayme (8). In a three-stage bleaching we could repeatedly find an increase in the strength properties which was, however, mostly connected also with a decrease in the ash. The most convenient method, however, is the three-stage bleaching in which a total amount of chlorine equaling about $^1/_{10}$ of the J-N number is required (with unwashed straw and unscreened pulp somewhat more, with washed straw and cleaned pulp sometimes somewhat less). But it has to be taken into account that, at least in the clorination phase but most conveniently in the after-bleaching, it must be operated with a certain excess. Besides, the consumption of chlorine in technical pulp production also depends very much upon preliminary and intermediate washing. With well digested material of a J-N number (ash-free) of 50-60 the bleaching loss regularly turns out to be 8 to 10%, at complete elimination of the ash. On a commercial production, however, there will always be a loss of ash and fines at the same time. The cleaner treatment after the bleaching process results in a removal of the grit and a noticeable brightening up. To the yield of bleached pulp we will return later, here we want to confine ourselves to the statement calculating with a bleaching loss of 8 to 10%, our average yield of 66% of unbleached pulp would turn out to be 60% in the bleached state (with ash correction and without loss of fines).

Fig. 12. Pulp from rye straw; fraction 1 (42×)

Fig. 13. Pulp from rye straw fines; fraction 5 (42×)

Table XI. Rice and Rye with Varying Amounts of Added Alkali at 125° and 170°C., 2 Hr.

All figures calculated on ash-free straw and ash-free pulp. Maximum values at 0 to 15 min. of beating time.

	Rice Ash: 17.1—17.6—15.3				Rye Ash: 3.8—4.8—0.9			
125°C.								
NaOH, %								
Added	8.4	10.8	14.5	19.3	7.7	9.4	12.5	16.6
Used	5.7	7.7	10.0	14.8	7.0	8.4	9.9	11.0
J-N no.	85	68	61	56	145	115	75	63
D.P.	955	1010	1080	1100	..	..	..	..
Yield, %	70.9	67.1	67.0	64.7	66.8	63.2	59.3	57.8
Ash, %	19.0	17.8	16.7	9.4	1.8	1.8	1.7	1.9
Strength properties (max. values)*								
Tensile breaking length, km.	5.2	5.6	7.0	8.0	8.3	8.2	9.2	9.5
Folding endurance	130	270	400	500	410	600	640	1100
Bursting area, sq. m.	24	26	30	37	45	46	55	55
Tearing strength, g. cm./cm.	96	95	100	101	107	111	111	119
Yield, bleached								
Pulp basis, %	85.0	88.5	92.1	91.8	..	..	91.0	91.6
Straw basis, %	60.0	59.3	63.4	60.0	..	..	..	..
170°C.								
NaOH, %								
Added	8.4	10.8	14.5	19.3	7.3	9.3	12.5	16.6
Used	8.1	10.2	12.0	16.5	7.3	9.1	12.0	15.1
J-N no.	86	68	54	52	166	130	78	86
D.P.	985	1015	1035	1095	..	..	..	..
Ash, %	23.1	22.7	19.1	12.5	3.0	2.7	1.9	1.8
Yield, %	64.1	62.0	60.6	58.8	62.6	58.5	54.6	51.4
Strength properties (max. values)								
Tensile breaking length, km.	5.3	5.1	5.4	6.9	7.2	7.6	8.0	8.5
Folding endurance	85	110	190	350	830	1050	1200	1370
Bursting area, sq. m.	25	24	28	34	43	41	46	50
Tearing strength, g. cm./cm.	96	82	105	107	115	123	133	143
Yield, bleached								
Pulp basis, %	87.7	91.0	92.0	92.0	..	..	93.8	93.5
Straw basis, %	56.1	56.5	55.8	54.1	..	..	51.1	48.4

Calcd. on moisture-free straw, the added amount was equal to rice and rye.
* Up to 15 min. beaking time.

COMPARISON OF RICE STRAW AND RYE STRAW

We do not want to return to the already stated differences in the structure of the plants, in the ash content, in the microscopic picture, and in the behavior during the washing process. However, in order to refer further to known technical facts we have applied our methods of investigation also to rye and give a compiled summary of the results.

A clear survey is given in Table XI. The additions of NaOH, when re-calculated as ash-free substance, became somewhat different here because of the ash difference between rice and rye, a fact which has to be given careful attention. With small amounts of chemicals rye apparently does react only slightly but is making up for this, as far as the degree of pulping is concerned, by increasing the amount added. With both kinds the yields are dropping considerably with increasing alkali and temperature. With rye, however, this is followed by a marked increase of the folding endurance and the tearing strength, a fact which with rice will probably be veiled only by the ash and fines. In order to reach the point of defibration, rye needs sharper cooking conditions. Under equal pulping conditions the degree of pulping (J-N number) of rye is higher by 10 points. Moreover, the following average figures are characteristic of the yields:

Table XII. Comparison of Yields

	NaOH, %	*Temp., °C.*	*J-N no.*	*Yield, %*
Unwashed				
Rice: 5 expts.	14.9	132	52	59.5
Rye: 9 expts.	15.6	147	61	53.5
Washed				
Rice: 52 expts.	14.2	123	53	66.4
Rye: 7 expts.	14.8	143	60	58.8

In both cases, as can be seen, the consequence of preliminary washing is a highly increased yield and this even more with rice than with rye, where one will always content oneself with a dry cleaning. Quite a considerable increased yield we find above with rice straw in contrast to rye, both in the unwashed as well as washed condition. The differences in the yield cannot be explained by the slight differences in the amount of alkali and the temperature. An experiment in which both these factors were kept equal still gave differences of over 3% (unwashed) and over 5% (washed) from straw in favor of the rice straw. In the bleached condition, the yields from unscreened material become almost equal, partly by differences in the bleaching loss. In the washed condition rice also in the bleached form was on an average about 5% (from straw) higher than rye. Bleaching losses with washed straw are approximately equal.‡ It must be stressed that, as usual in the foregoing compilation, all figures have been re-calculated on an ash-free straw and ash-free pulp.

This increased yield, however, does not gain prevalence with rice because, being processed in exactly the same way, rice suffers corresponding and even higher processing losses, and this both at the cleaner treatment as well as at the dewatering on the sieve. In both cases there are concerned probably the same substances, namely, epithelial and parenchyma cells, which do not separate as easily as the fibers. Aggregates of these cells constitute the grit which is removed in the cleaner; individual cells occur as fines. The disengagement of these aggregates by means of pumps and refiners leads to an undesired increase of the degree of beating, which normally lies about 30°S.-R. On this the beating rate is more rapid with rice straw pulp than with rye.

Only the epithelial cells with rye are to be found from the beginning more individually in the fines than in the grit, which probably might simply be due to the inevitably stronger cooking conditions with rye.

‡ This difference in the yield is not only due to the nature of the material but also to the cooking conditions which with rye are necessarily sharper.

All these characteristics are more strongly marked with rice than with rye, as it becomes clear already from the fiber fractionations described above, which with rice showed about 50% more fines than with rye. But it could also be shown that by sorting, the fiber spectrum of the straw is much less changed—almost not at all—compared with rice straw. However, it is not advisable—at least not with rice—to prevent such screening losses by technical measures. With three experiments we found, on an average, the following changes to occur in the strength properties by the sorting process, the losses with rice in the cleaner and on the sieve amounted to about 10% each, with rye about half that much (Table XIII).

Table XIII

	Beating degree, %	*Tensile strength,* %	*Folding endurance,* %	*Burst area,* %	*Tearing strength,* %
Rice	−12	+3	+242	±0	+27
Rye	−7	+1	+50	+4	+7

The decrease of the degree of beating is as much desired as the increase of the folding endurance and the tearing strength. The removal of grit and fines having almost the same effect here, it is sufficient just to characterize the common effect.

These conditions now are responsible for the fact that with rye—without preliminary washing and without screening losses—there are easily obtained the same or even higher strength properties than with rice after a screening with many losses. We are pointing here once again to the typical average values of Table VIII.

The influence of temperature, which with rye straw necessarily lies about 30° higher, does not play an important part here. But there is no doubt that with rye it would have been possible to increase by sorting still further the folding endurance and the tearing strength. Several top values, both with rice and rye straw, were even essentially higher.

SUMMARY

Comparing the rice straw with rye we can state, on the whole, the following:

With rice straw the proportion of halm and leaves, and therefore that of fibers and surface cells, is far more unfavorable, the pollution is higher because of the rough surface of the stems, the content of ash is about 5 times as high (the silicic acid being about 10 times as high), and also the water-soluble substance was higher, at least with our raw material.

On the other hand, referred to ash-free substance in the washed condition, rice straw gives higher yields so that with it a certain amount of processing and cleaning losses can be afforded. Rice requires a lower cooking temperature, i.e., less steam and less chemicals, and it gives, in the unbleached state, a whiteness of about 10 points more.

The cleaning losses in the straw sorting as well as in the pulp sorting are correspondingly higher. If these losses are avoided the strength properties are much worse, whereas with rye the losses are smaller, and as for the strength properties, they are not important. With rice, there must be removed a lot of fines and ash for reaching approximately the strength properties of rye, and furthermore, with unsorted rice straw pulp, there is easily developed too high a beating degree.

Finally, its fibers are much thinner, a fact which surely is of great importance for the quality of paper. In this field, the technical experiences still have to be confirmed by experiments.

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Received Dec. 11, 1959. Presented at the EuCePa Symposium on Straw Pulp, held in Noordwijk, Holland, June 1, 1959.

Standardization of Model C Mullen Testers in a Multimill Company

LYMAN C. ALDRICH

The need for large amounts of information as a prerequisite for satisfactory interlaboratory standardization is discussed and some standardization services enumerated.

A new air clamping device for model C Mullen testers was evaluated and the effect of clamping pressure on paper and foil samples is shown. Other clamping variables are discussed. Possible causes of errors and methods for correcting these errors are given. The effect of air in the system is discussed and methods for removing air from both the gages and the hydraulic system as a whole are presented.

West Virginia Pulp & Paper, like most of the other large multimill companies, has undertaken the standardization of testing procedures among its different mills. This standardization has become increasingly important in the last few years of tighter specifications, more technical know-how, and keener competition.

West Virginia recently began the task of obtaining agreement among more than twenty different model B and C Mullen testers at its different mills. There were numerous problems which required solution before agreement could be obtained, and subsequent investigations gave some surprising results. Most papermakers are probably aware of some of these facts, although their magnitude may be astonishing. It is hoped that this paper will be useful in saving others the time required to compile this data from the many different available sources and thereby enabling them to help on tests still undone.

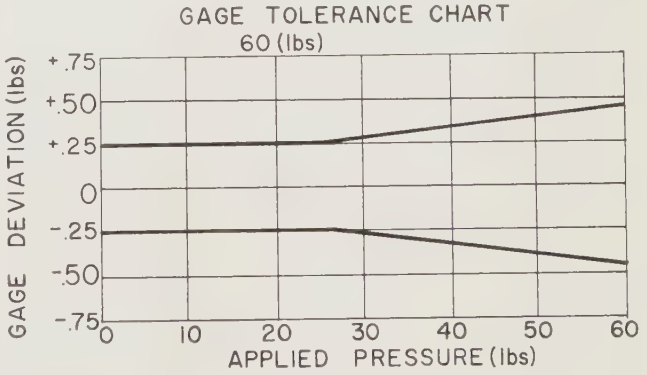

Fig. 1

Since the Mullen burst is essentially an empirical test, standardization requires the checking of individual instruments against standard foil and/or paper samples, or against each other on similar samples. We have found negligible operator differences so the main standardization work consists in correcting differences among instruments.

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PROBABLE CAUSES OF ERROR IN AN INSTRUMENT

The following check list may be useful in locating causes of error in an instrument. It is, necessarily, far from complete.

(a) If reading low throughout scale:
  1. Gages reading low
  2. Clamping heavy in center
  3. Air in system
  4. Weak diaphragm
  5. Diaphragm too low
  6. Excessive drag of maximum pointer

(b) If reading high throughout scale:
  1. Gages reading high
  2. Clamping light in center
  3. Low clamping pressure
  4. Improper clamping
  5. Stiff diaphragm
  6. Diaphragm above diaphragm plate

(c) Correct for low readings but high for high readings:
  1. Gage
  2. Low clamping pressure

(d) Correct for low readings but low for high readings:
  1. Gage
  2. Air in system

(e) Correct for standard foil samples but high for standard paper samples:
  1. Low clamping pressure

(f) Variable results:
  1. Maximum hand on gage
  2. Cocking of clamps
  3. Variation in diaphragm height
  4. Combination of different partially compensating variables

GAGE

Model B and C Mullen testers normally use either of 2 types of maximum reading gages—Acragage and Ashton gage. The Pulp & Paper Research Institute of Canada published a report of an extensive study on gages (*1*) and numerous people at other laboratories have made studies so less time will be spent on this source of error. All gages should be checked at regular intervals not to exceed 3 months. The gages should also be checked where physical damage indicates the possibility of gage error. It is advisable to check with a normal dead weight tester at least 5 different loadings to assure accuracy throughout the scale. Gages should check within the limits as indicated in Fig. 1 or 2. These data are from "Maintenance and Standardization of Paper Testing Instruments" by G. C. Kimble of Union Bag-Camp Manufacturing Company (*2*).

The checking against a master gage is also satisfactory in most cases. All air should be removed from the gage before use. Unfortunately, dead weight testing and testing on a standard gage will not normally indicate the presence of air.

Figure 3 shows a simple device assembled from normal laboratory equipment for removing this air. It is best to remove the air using several cycles of evacuation and filling. If necessary, Acragages may be bled on the instrument through the bleeder tube. However, if this is done, the gage must be rotated numerous times to be sure of complete removal of the air at the tip of the Bourdon tube.

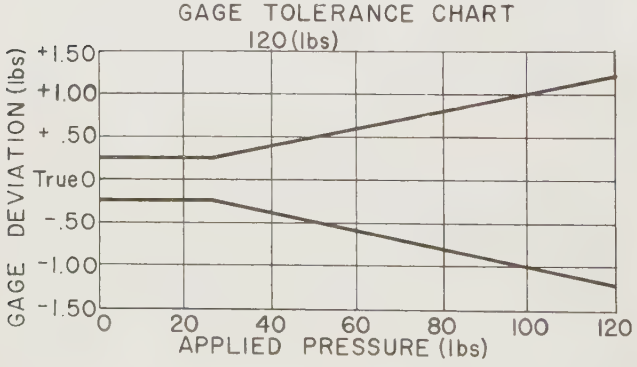

Fig. 2

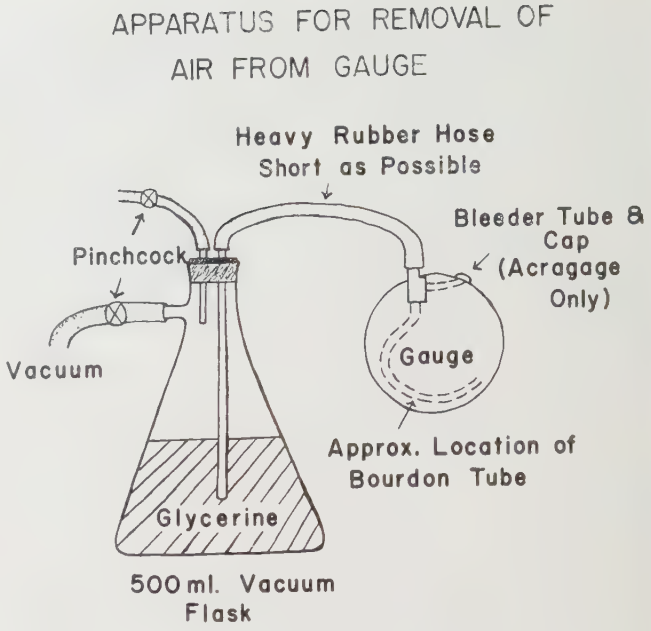

Fig. 3

Gage Pointers

Maximum hand pointers on Acragages are a constant source of trouble. They should be tight enough so that they will not jump, but must be loose enough so that rotating the maximum hand clockwise will not force the indicating pointer more than halfway around the gage. Perkins is coming out with a new maximum hand pointer for the Acragage which should reduce this problem.

Location of the Gage

Some laboratories install the gage in the end of the cylinder rather than the normal location. We have been unable to find any real difference in values due to this change in location.

CLAMPING OF THE PAPER

Improper clamping is probably the greatest cause of erroneous results in the Mullen burst test. We have found that lack of visible wrinkling during the test is no assurance that clamping is adequate.

Clamping Pressure

B. F. Perkins has designed and built an air loaded clamping attachment for the model C tester. We obtained the pilot model and have evaluated this clamp.

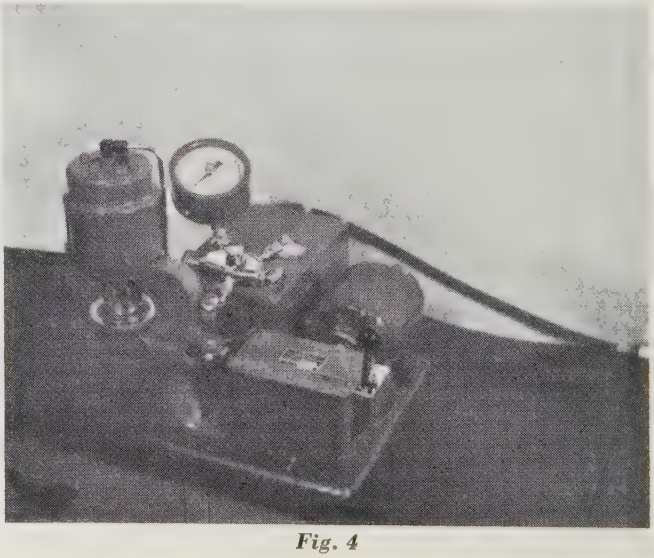

Fig. 4

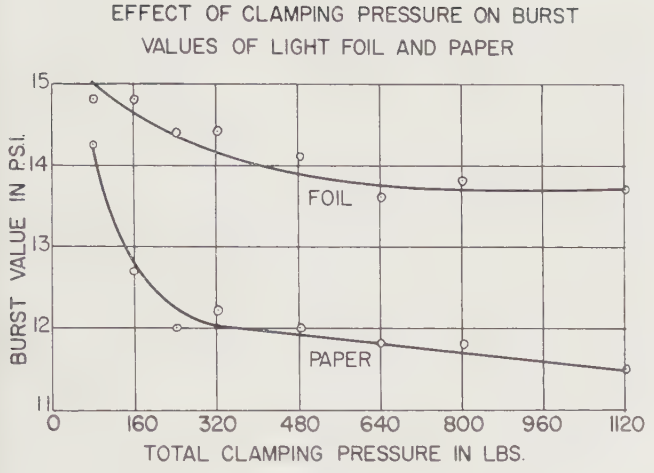

Fig. 5

Figure 4 shows a picture of the clamp with auxiliary reducing valve and other equipment attached to our tester. The 16-sq. in. piston is sufficiently large to obtain 500 lb. clamping pressure with air at 32 p.s.i.

We found that variations in clamping pressure can cause up to 15 or 20% errors in readings. Three different aluminum foils and three different papers were tested using a range of from 80 to 1100 lb. total clamping pressure. Figures 5, 6, and 7 show the effect on these foil and paper samples.

Figure 8 averages the data of the previous figures but as a percentage of the value at 500 lb.

It is interesting that foil levels out much sooner than the paper so a combination of foil and paper standard samples may give a fair indication of whether clamping pressure is the cause of testing errors. Most paper mill personnel are aware that insufficient clamping can cause high test values. Nevertheless, the magnitude of these errors may be surprising. The strong papers with light clamping pressure did show visible wrinkling and creeping. However, all visible signs of improper clamping ceased before any leveling out of test value was apparent. TAPPI Standard T 403 has no specification for clamping pressure so that any value over most of this range is technically correct.

An air-operated clamp is probably the simplest and cheapest method for obtaining reliable clamping pressure. We are in

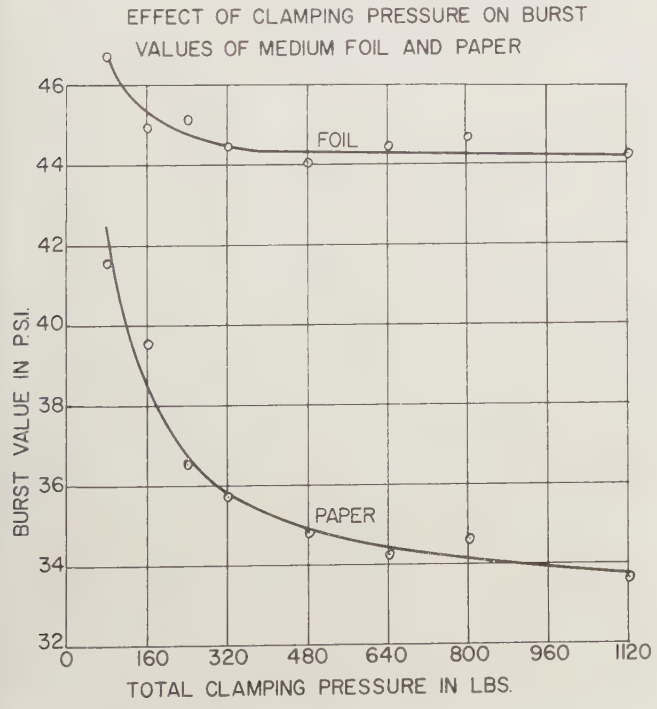

Fig. 6

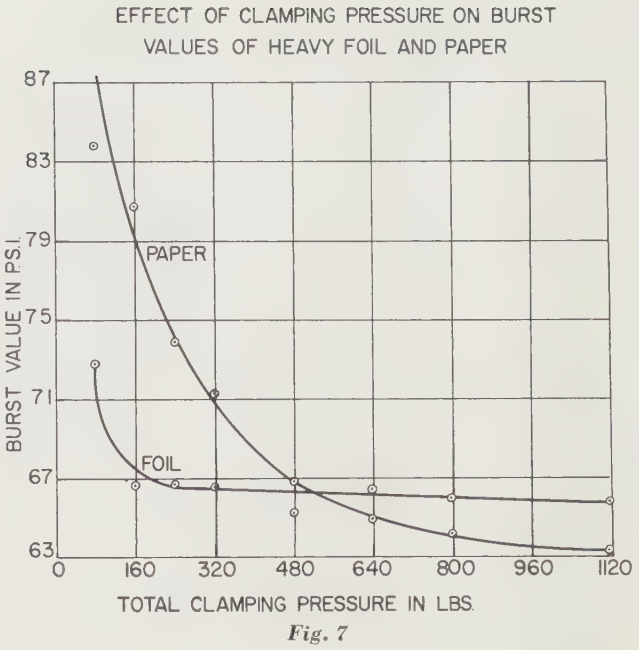

Fig. 7

the process of installing them on West Virginia instruments. The Institute of Paper Chemistry uses deflection gages to measure their clamping pressure which is quite accurate but would probably not be satisfactory for paper control instruments. We, in West Virginia, have arbitrarily and temporarily decided on 500 lb. total clamping pressure for our clamps because of our belief that this is probably about average for the industry. The Institute of Paper Chemistry, B. F. Perkins and others, as well as our work, indicates that a higher clamping pressure may be desirable. The exact pressure should be decided by the appropriate TAPPI Committee and written into the TAPPI Standard.

Since most laboratories do not have air operated or hydraulic clamping on model C Mullen testers, a fairly good estimate of clamping pressure can be obtained by determining the compression of the main clamping spring, calculating fulcrum distances and ratios, and adjusting the knob to obtain the desired spring compression.

The brass lever is subject to excessive wear. It is most important to keep the lever lubricated with heavy grease, occasionally file down the stop so as to maintain necessary eccentricity, and frequently check for proper clamping pressure.

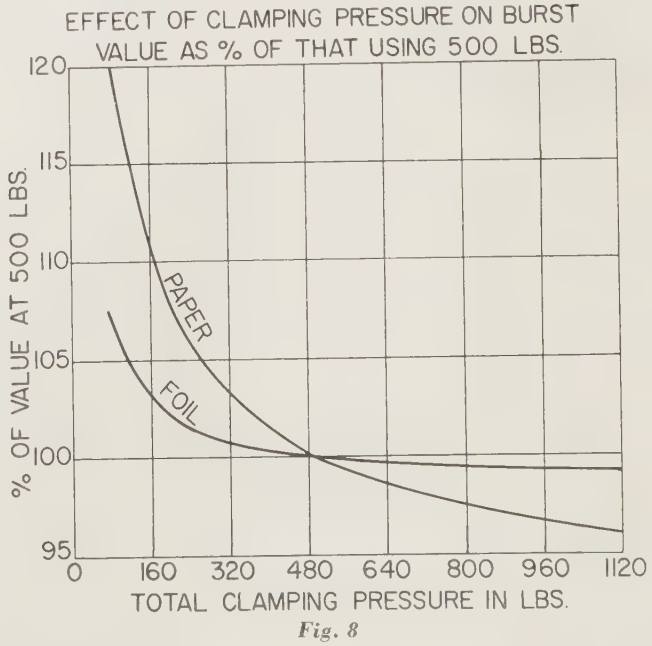

Fig. 8

Fig. 9

Lack of eccentricity of the lever is dangerous because it can cause the lever to hop up and reduce clamping pressure after the operator's hand is removed.

Condition of Clamping Plates

While the clamping plates will not give differences as great as differences in clamping pressure, plates can still cause an error of 2 to 3 lb. in the readings. Figure 9 shows four different conditions of plates that may be encountered.

It is very simple to obtain a plate impression by placing a piece of pencil carbon (regular typewriter carbon will not work) against a single sheet of thin paper and clamping using normal procedure. Impression "a" is, of course, the desired impression. Impression "b" is frequently found where the diaphragm plate has collapsed over a period of time from extensive use. This requires replacing the diaphragm plate. Impression "c" occasionally happens with a brand new plate where the center is high. This can be corrected by lapping the diaphragm plate or by obtaining another plate. Impression "d," which occurs infrequently, indicates that the upper tripod plate has collapsed between the posts and needs replacement. Included, under the impressions "a," "b," and "c," are values on a foil and paper sample for similar plates which gives an indication of the magnitude of errors that can be expected.

RUBBER DIAPHRAGM

Contrary to TAPPI Standard T 403, the gage should show a pressure between 3.5 and 5 lb. upon $^3/_8$ in. distention of the diaphragm. This lower value is due to the change in design of the diaphragm plate several years ago. Our personal experience is that diaphragms are usually within these limits over a considerable period of time and that errors due to the diaphragm itself are small compared to other errors. However, this diaphragm distention should be taken into consideration where very weak papers are normally tested. A properly installed diaphragm should last for a considerable length of time. Our experience has been that replacement was usually required because of extensive wrinkling which is usually the result of improper installation. We have worked up a rather elaborate procedure for replacing diaphragms. While it appears to be quite tedious, we have found it worth while. Following is our recommended method for installing diaphragms.

1. With the motor running, place the Mullen tester in the low pressure automatic stop position. Turn off tester.
2. Remove diaphragm nut, diaphragm plate and old diaphragm.
3. Remove plug at end of tester and drain glycerin so that it is approximately $^1/_4$ to $^1/_2$ in. below the surface.
4. Clean the rings thoroughly first with water and, if necessary, with acetone or alcohol. It is important that these clamping rings be meticulously clean and free from old glycerin so that the diaphragm will not slip after being positioned. Also clean lower surface of diaphragm plate.
5. Using the fingers, stretch the diaphragm several times. The diaphragm will not be flat after this stretching but this should not cause worry.
6. Place the diaphragm on the clean, dry grooves. Install diaphragm plate and partially tighten diaphragm nut.
7. Install tripod with tripod plate. Lower to clamping position and hand-tighten diaphragm nut. It is wise to raise and lower the tripod plate several times in order to seat properly the diaphragm while hand tightening diaphragm nut.
8. Tighten the diaphragm nut approximately a quarter turn with a spanner wrench. Check impression of plate using a sheet pencil carbon with a sheet of onion skin. If center impression is light, tighten diaphragm nut with a spanner wrench. If outside edge of clamp appears light, loosen diaphragm nut slightly (the nut must be at least hand tight in order to satisfactorily hold the diaphragm). If the center is still heavy, then the diaphragm plate must be lapped or replaced.
9. Tip entire tester on its side so that the plug is on top and the diaphragm is in a vertical position.
10. Unscrew plug and add glycerin to overflowing. With finger, press diaphragm in and out several times to force any air bubble out through plug opening while filling.
11. Replace plug, lower tester to normal position.
12. Turn on motor. Raise diaphragm, then lower to automatic stop position. Bleed excess glycerin out through bleeder tube of gage. Diaphragm should be level with top of diaphragm plate in automatic stop position.
13. Using the motor, distend to full height and return several times to again limber up the diaphragm. (Diaphragm will not burst if properly installed.)
14. Raise the diaphragm to $^3/_8$ in. and check gage pressure. The gage pressure should be between 4 and 5 lb.
15. Raise diaphragm to full height and observe if there is an air bubble under the diaphragm (the diaphragm is sufficiently transparent when stretched to this extent). If an air bubble over $^1/_4$ in. diameter is apparent, return to automatic stop position, turn up the tester so that plug is on top and repeat steps 10, 11, and 12.

It should be noted that the filler plug, located near gage at end of hydraulic line (No. 79 on Perkins' drawing), is never opened in this operation. The use of the filler plug frequently gets air into the gage end of the system so it is best not to touch the gage end of the hydraulic system except during the final bleeding.

In connection with the rubber diaphragms, we have found excessive wrinkling as well as the height of the diaphragm to be quite important. The diaphragm should be as wrinkle-free as practical. As everyone knows, this is a very difficult task, but our procedure does as good a job as any in this respect. It is also important that the diaphragm is not above the diaphragm plate because this tends to pre-wrinkle and warp the sheets, thereby giving erroneous high values. The diaphragm, when in return position, should not be any farther below the plate than is necessary due to possibility of trapped air between the sample and diaphragm. This air can have the same effect as air in the system in slowing down the pumping rate and giving an erroneous low value. This causes negligible differences in a very porous sheet but can have noticeable effect on coated papers. Some laboratories have even gone so

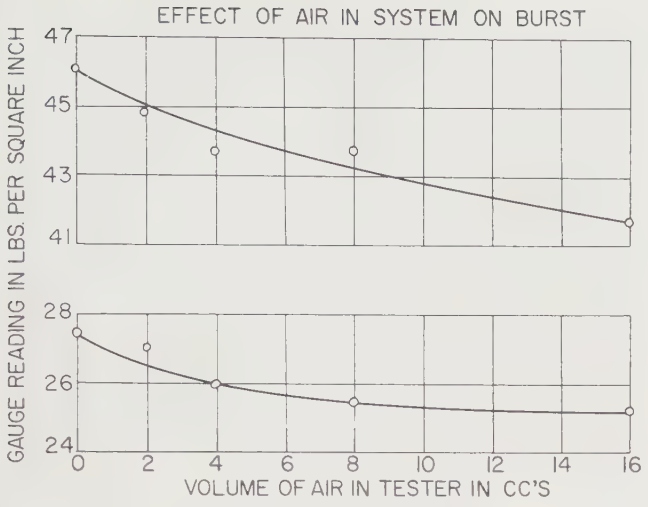

Fig. 10

far as to cut grooves in the diaphragm plate to allow this trapped air to escape.

AIR IN THE HYDRAULIC SYSTEM

Air in the hydraulic system results in a gage reading below the true bursting value due to lower effective pumping rate. A paper by Tuck and Mason (*1*) of the Pulp & Paper Research Institute of Canada includes some studies on this effect. Figure 10 uses Tuck and Mason's data to show the effect of different quantities of air on two samples of paper.

It is worth while to check for air in the system even though recommended procedures have been used to remove air from both the gage and hydraulic cylinder. This is easily done using the following procedure:

1. Turn off the motor and pull the cord so that the motor cannot be accidentally started.
2. Obtain a piece of steel plate or inflexible material and clamp between the plates.
3. Push the lever handle to the left and rotate the shaft by hand until a gage pressure of 10 lb. on a 120-lb. gage or 5 lb. on a 60-lb. gage is obtained.
4. Allow air trapped under the plate to escape by slowly turning the shaft until the 10- or 5-lb. reading is steady.
5. Rotate the shaft between the gear box and the hydraulic head an additional 180°. A 120-lb. gage should read over 40 lb. or a 60-lb. gage should read over 20 lb. A lower reading indicates there is excessive air in the system.

HYDRAULIC LIQUID

TAPPI Standard T 403 m-53 specifies that ethylene glycol should be used as the hydraulic liquid. This was changed from the previous Standard, T 403 m-52, which specified glycerin. Some TAPPI members believe that a mistake was made in changing the fluid. It is easier to bleed air from glycol but it is more difficult to prevent leaks in the hydraulic system. We made a study comparing glycol which was 18 centipoise viscosity and glycerin-water mixtures which were from 20 to almost 300 centipoise viscosity. We found negligible differences due either to the type or to the viscosity of the hydraulic fluid provided the system is free from air. Therefore, two instruments operating with different hydraulic fluids should check satisfactorily.

GENERAL STANDARDIZATION NEEDS

It is hoped that this limited compilation of data, much of which was obtained from outside sources available to everyone, may make it easier for others to maintain their burst testers in satisfactory calibration.

The standardization of the many different tests (there are about 210 TAPPI Standards, over 260 Routine Control Methods, and everyone is familiar with many more from other sources) is a large undertaking and yet a necessary one. Granted that everyone does not use all of these tests, there is still an enormous task to do. To complicate this task, much of the information required to arrive at the same test results at different locations is not readily available. This results in an expensive and inefficient procedure whereby laboratories throughout the country independently run numerous correlation experiments. No one company can be expected to do all the investigations required to standardize all of the necessary tests. All concerned will have to work together or the work simply will not get done.

The industry has been groping for some time with varying degrees of success in standardizing many of our tests. Following is an incomplete list of some of the standardization work currently being carried out:

1. The G.E. brightness test is probably the best standardized test in the industry. The Institute of Paper Chemistry sends out standards and standardized tabs of paper each month to all instrument owners who subscribe to this service.
2. The Fourdrinier Kraft Institute has for some time had a monthly check on 42-lb. linerboard from its numerous participating mills. In conjunction with these monthly tests on board, they check the Jumbo Mullen, tear, caliper, and basis weight of the participating laboratories.
3. The Institute of Paper Chemistry, in conjunction with APPA, conducted a round robin on burst, tear, and brightness, which indicated a great need for standardization of tear and burst and showed the standardization work on brightness was relatively successful.
4. More recently, the National Bureau of Standards, in conjunction with APPA, has conducted a round robin on tear and is contemplating standard paper tabs with assigned values for this test. There are tentative plans for enlarging this work to include other tests.
5. The Pulp & Paper Research Institute of Canada has for years checked Canadian Standard Freeness Testers before shipping to customers, but there has usually been no recheck on instruments even after years of service.
6. The Pulp & Paper Research Institute of Canada, as well as some other laboratories, has for years supplied aluminum foil samples with assigned burst values.
7. The Institute of Paper Chemistry has made numerous instrumental studies. There are other standardization services in existence.

All of these studies and services are a good start. This type of information and services now needs to be consolidated within a single clearing house type of group and this work augmented to fill the areas not now covered. This group should be able to supply samples with assigned test values and the information and help necessary to bring tests into agreement. It will require considerably more information on the effect of different models and modifications of both instruments and procedures through the years. The group will need all the help and data different companies in the industry can give.

Even after obtaining a centralized source of standard samples, help and information, a large amount of effort will be required at each laboratory to accomplish the ultimate goal of having the industries tests accurate and in agreement.

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Received Oct. 2, 1959. Presented at the 10th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Portland, Ore., Aug. 17–21, 1959.

The author wishes to thank J. F. Fridley for assistance in making a large proportion of the tests; B. Q. Haynes and others with B. F. Perkins and Son for cooperation on the clamping attachment; S. M. Chapman of PPRIC; W. A. Wink of IPC, and others in W. Va. P & P Co. for their help and advice.

Digester Corrosion Experience at Union Bag-Camp Paper Corporation

H. B. HARRIS and L. H. PARK

Union Bag-Camp Paper Corp.'s experience with corrosion in sulfate digesters is unique in two important respects. First is the fact that it relates to an unusually large number of digesters operated under like conditions in a single mill; and second is the additional fact that it reflects comparable performance of several different materials of construction used in digesters operated under very similar corrosion exposures. Data are available on a total of 61 individual vessels. These data cover the entire life span of 23 digesters that have been removed from service, and varying portions of the life span of 38 other vesels which are still in use.

The original 13 digesters installed in our mill were of ASME S1 firebox quality steel. They were installed in 1936, and were used continuously in sulfate service until replaced 13 to 15 years later. During the period 1942 to 1948, seven additional digesters were installed in similar service. Four of these vessels were of ASTM A 70 steel, and three were of A 285 Grade C steel. By 1950, when it became necessary to replace some of the original digesters installed in the mill in 1936, it was clearly evident that the newer A 70 and A 285 vessels were corroding at a much more rapid rate than the original units made of S 1 steel. This development obviously focused attention on the digester corrosion problem, the impact of which we had not heretofore fully realized. The seriousness of this problem was further emphasized by reports from other mills of rapidly increasing corrosion rates in their digesters. One of several avenues of attack on this problem was that of experimenting with alternate materials of construction which offered the possibility of increased corrosion resistance. Our management decided to do just this, but at the same time not to neglect other approaches of the problem. This decision led eventually to the installation of:

Three digesters made of ASTM A 212 steel.

One digester made of ASTM A 212 steel lined with 3-in. thick carbon brick.

One digester of 316 Columbium stabilized stainless clad over an A 212 backing steel.

Five digesters of Inconel clad over an A 212 backing steel.

Four digesters of rimmed A 285 steel.

Three digesters of a special rimmed A 285 steel identified as Oxyrim.

Later replacements and mill expansions led to the installation of other A 285 steel digesters, and to one group of eight A 285 steel vessels with four-inch carbon-brick lining.

It is, thus, our primary purpose in this paper to report our experience with these several different materials of construction.

OPERATIONS

All but five of the 61 digesters from which our experience is drawn are, or were, used for the production of kraft pulp. The other five are used approximately 85% of the time in neutral sulfite semichemical service, and the remainder of the time in kraft service. The five vessels used for semichemical service are equipped for forced liquor circulation. Natural circulation only is used on the 33 vessels in kraft service. Cooking is accomplished by direct steaming in all cases. Cooking and filling operations have varied somewhat over the years, but have approximated the following procedure:

Chips are charged to the digesters through a nozzle in the top of the vessel by gravity flow from the chip bin above the digester room. After a digester is completely filled with chips, a measured amount of liquor is introduced through a 6-in. diameter pipe. The liquor fill pipe discharges vertically at the center of the chip-charging nozzle. After the liquor has been charged, the vessel is capped, and 110 p.s.i. saturated steam is introduced through four steam nozzles at the bottom cone of the vessel. Approximately 1 hr. is required to bring the digester to temperature and pressure. Cooking then continues at constant temperature and pressure for 1 to $1^1/_2$ hr., depending upon the type of pulp desired. When the cook is completed the blow valve at the bottom of the digester is opened, and the pulp is discharged through the blow line by steam pressure.

Figure 1 shows the typical design and dimensions of our digesters. They are approximately 10 ft. in diameter and 42 ft. high. Thirty of the vessels now in operation are insulated with 2-in. thick foam glass. The remaining eight vessels are carbon-brick lined and have no external insulation. All of the digesters are of welded steel construction.

Digesters in our Savannah mill are inspected on regular schedules and results are reported on standard TAPPI report forms. Visual internal inspections are made on all vessels. Audigage measurements are taken from the inside of all carbon steel vessels, and from the outside of all brick-lined vessels. G.E. magnetic-thickness gage measurements are taken from the inside of all the alloy-clad vessels. Current corrosion rates are calculated at each inspection to highlight changing corrosion conditions. Remaining life calculations are based on corrosion rates extrapolated from curves showing life span corrosion trends of critical areas of the vessel. Such inspections were made semi-annually up until 2 years ago, when inspections were rescheduled on an annual basis.

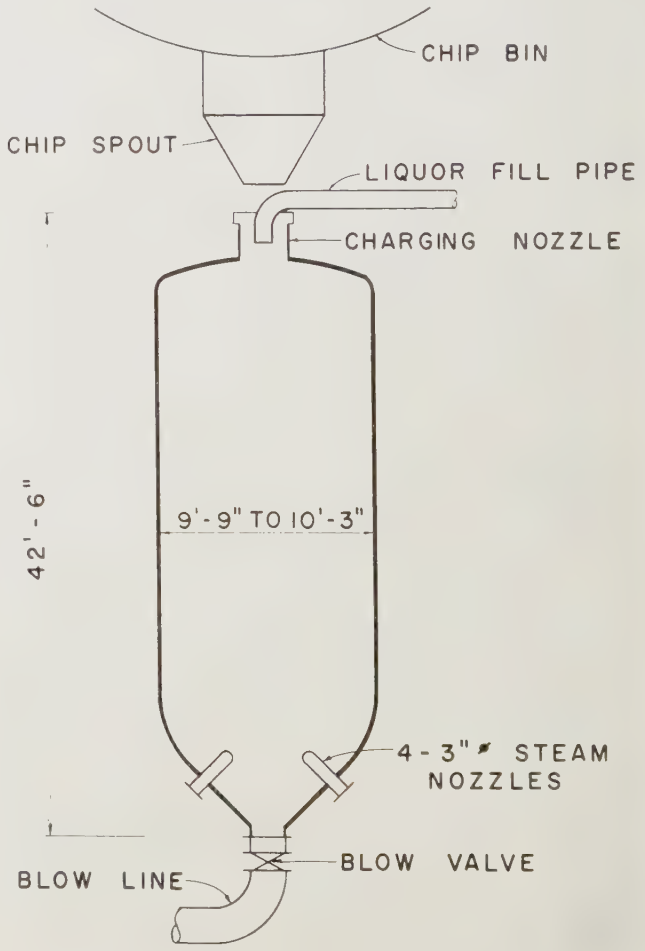

Fig. 1. Typical Union Bag kraft digester

H. B. Harris, Jr., Mill Engineer, and L. H. Park, Group Leader, Mill Engineering Dept., Union Bag-Camp Paper Corp., Savannah, Ga.

CARBON STEEL DIGESTERS

The original 13 digesters installed in our plant were made of $1^1/_{16}$-in. thick ASME S 1 carbon steel. These vessels had a useful life of 13 to 15 years, and an average life span corrosion rate at the critical areas of 0.035 in. The life span critical area corrosion rate of a group of seven A 70 and A 285 vessels installed in the 1942 to 1948 period was twice that, or 0.075 in. per year. Our experience with these two groups of digesters tied in nicely with the then prevalent theory that the corrosion resistance of postwar steels was inferior to that of prewar steels. Our first attempt to find a more resistant carbon steel led us in 1950 to the installation of three ASTM A 212 firebox quality steel vessels. It was soon apparent, however, that this was a step in the wrong direction. The corrosion rates in these vessels averaged 0.121 in. per year—over one and one-half times the rate of postwar digesters, and three and one-half times that of the prewar ones. This experience confirms the now generally accepted theory that the silicon content of digester steels should be kept as low as possible. By 1952 we were convinced that A 285 steel was the best carbon steel available for digester service. It was, therefore, decided that future carbon steel vessels would be of A 285 steel, and that the original thickness of the vessels be no less than 2 in.

However, 1952 and 1953 saw a further attempt to duplicate the performance of prewar steels with the installation of four 2-in. thick A 285 firebox quality rimmed steel digesters. At about the same time, we chose to determine more accurately the effects of mill scale on corrosion rates, and installed one group of four A 285 vessels, two of which were carefully sand blasted prior to being put into use, and two in which the mill scale was left in its "as is" condition. The corrosion resistance of the rimmed steel proved to be no better or worse than that of less expensive semikilned steels. Likewise, there has been no apparent improvement in the performance of the two vessels from which the mill scale was removed. Our most recent experience with modified A 285 steels was with three vessels made of a special rimmed steel identified as "Oxyrim." These units were installed in 1956 and, thus far, there is no indication that they are any better than conventional A 285 steels.

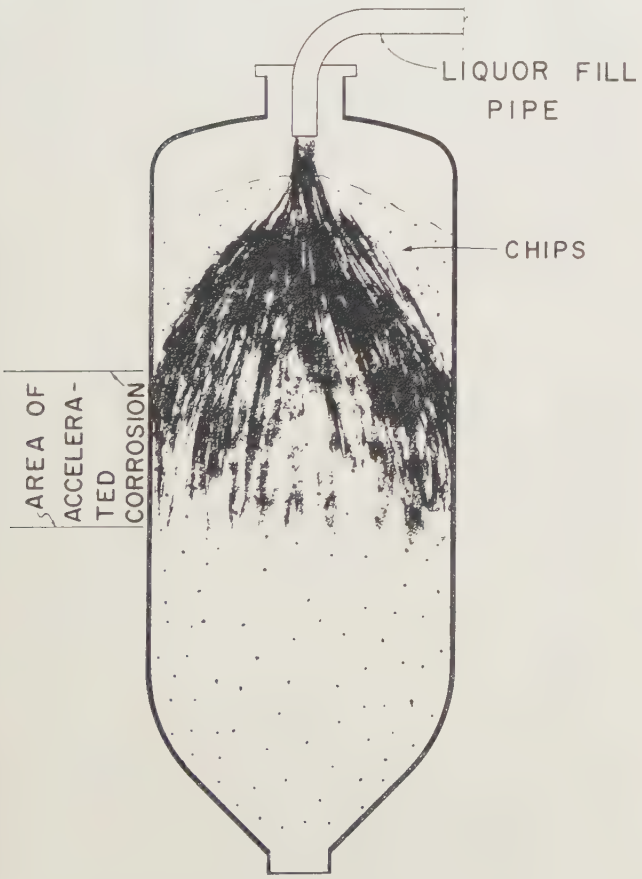

Fig. 2 Present method of liquor charging

The current average corrosion rate of carbon steel digesters in our mill is about 0.02 in. per year. The current average corrosion rates in the critical areas of these digesters is about 0.08 in. per year. These rates approximate the weighted averages of those vessels being reported each year through the TAPPI Regional Digester Activity program. They do, however, indicate the need for continuing effort in our mill, as well as many others, to narrow the spread between the average and critical area corrosion rates. The pattern of corrosion in our digesters is fairly uniform around the circumference of the vessels. It varies in the vertical direction, however, from a relatively minor rate in the head and cone sections to a maximum rate in the middle shell. We believe that this preferential attack results from hot-plate boiling which takes place during the liquor-filling operation. Figure 2 shows how, we believe, the liquor diffuses through the chips to the shell of the vessel, causing local attack in the middle shell area. We have as yet found no acceptable method of eliminating or controlling this problem.

ALLOY-CLAD DIGESTERS

Concurrently with the trial of various carbon steel digesters, Union Bag-Camp installed six clad digesters in 1950 and 1951. Five of these were 1-in. thick 20% Inconel-clad digesters, and one was a 1-in. thick 20% Type 316 columbium stabilized, stainless-steel clad digester. To date, only three of the five Inconel digesters exhibit any detectable corrosion rate. The corrosion rates of the Inconel clad vessels vary, then, from 0 to 0.006 in. per year, and from 0 to 0.002 in. per 1000 cooks. The corrosion rate of the stainless steel clad vessel is 0.009 in. per year, or 0.004 in. per 1000 cooks.

The critical areas of our carbon steel digesters are, without exception, in the middle shell. The critical areas of all clad vessels, however, are near the top of the shell, definitely in the vapor zone. This fact indicates that alloy-clad vessels are practically immune to attack by sulfate liquor, but are slightly attacked by vapors driven off during the cook. It is also apparent that corrosion, as distinguished from erosion, is the primary factor in the deterioration of kraft digesters. If this were not true, the geographic location of the corrosion-erosion patterns in the alloy-clad digesters would compare more closely with the plain carbon steel vessels. Actually, however, there has been no noticeable metal loss below the liquid level in any of the clad digesters.

CARBON-BRICK LINED DIGESTERS

In 1950 an ASTM A 212 Grade B firebox digester having a 3-in. carbon-brick lining was installed in kraft service. In 1953, six ASTM A 285 Grade B firebox vessels having 4-in. carbon-brick linings were installed in neutral sulfite service. In 1957, two more such lined digesters were installed for semichemical service and, at the same time, three of the original six such vessels were changed to kraft service. The years have proved the complete immunity of carbon brick to both the neutral sulfite and sulfate liquors. Unfortunately, the same cannot be said for the mortar used to hold the bricks in place. Union Bag-Camp's experience has been that mortar made from portland cement and quartz aggregate, as recommended by the brick lining suppliers, will corrode to a depth of about $^3/_4$ in. in 2 to 3 years. It has been the practice to re-point these vessels periodically when the mortar joints become $^3/_4$ to $1^1/_2$ in. deep. Re-pointing mortar joints before they are at least $^3/_4$ in. deep does not usually result in sufficient bond between the brick and the mortar, and early failures are likely.

Mortar joints are occasionally attacked preferentially, resulting in deep holes about $^1/_2$ to $^5/_8$ in. in diameter, and extending 1 in. or more below the adjacent mortar. There have been two instances at Union Bag-Camp where these holes extended through to the shell, and small pits were found in the steel. Usually, however, these holes are revealed by routine inspections before they have had a chance to progress so far.

Some cracking and spalling of the brick has been encountered. However, no instance has been recorded where damage to the brick alone necessitated repairs. All cracked brick have cracked parallel with, rather than normal to the face of the brick. There is little possibility, then, that liquor will seep through a crack in the brick to corrode the steel shell behind.

Owing to mounting repair costs and down time, it became necessary early this year to remove the 3-in. brick lining from one of the digesters used in kraft service. An inspection of the steel shell made immediately after removal of the lining revealed fairly large areas washed up to $^1/_8$ in. deep, and several isolated pits up to $^3/_8$ in. deep. The deep pits were repaired with E-7010 rods, and the digester returned to service without relining. This lining had been in service for $8^1/_2$ years, and apparently during most of this time had protected the steel shell from corrosion. The fact that liquor did manage eventually to get behind the lining to the shell points out the necessity for frequent and careful inspection of brick-lined vessels.

MANUALLY APPLIED WELDED OVERLAY

One of Union Bag-Camp's earliest attempts to control the effects of preferential corrosion in local areas of its digesters was the application of Type 310 stainless steel welded overlay. The philosophy behind using stainless steel overlay was merely to extend the life of the digester by covering those areas which were corroding rapidly. Some success was achieved. However, the disadvantages of this "small area" type protection seemed to outweigh the advantages. Once the overlay was applied, each subsequent inspection revealed the necessity for its extension. For example, 128 sq. ft. of Type 310 stainless steel overlay installed in an ASTM A 70 vessel in October, 1953, was extended five times to a total area of 220 sq. ft. prior to the digester's removal in August, 1957. Rapid attack in the form of undercutting of the plain carbon steel at the edge of the overlay was experienced in every instance. This occurred regardless of the addition of carefully applied peripheral weld beads. While the attack was usually most severe along the lower edge of the overlaid area, it was well defined around the entire periphery.

In most cases, the only visual indication of any deterioration of the overlay itself was a few scattered pinholes which were observed after three years of service. These were apparently the result of faulty application rather than corrosive attack of the stainless steel.

Our experience with the use of overlay on washed weld seams was very much the same, and the use of stainless for this purpose has been discontinued. Weld seams are now repaired when required with carbon steel overlays. As weld seam corrosion continues to be a problem in our mill, three of seven new digesters now being installed for hardwood kraft operations contain weld seams made with rods of varying composition, installed by both machine and hand welding techniques. Experience with these vessels should indicate preferred materials and application methods for weld seams.

CONCLUSIONS

The several conclusions drawn from this experience are:

1. ASTM A 285 firebox steel is the best steel now available for sulfate digester construction. The corrosion resistance of rimmed types does not appear to be superior to semikilned types.

2. Inconel and Type 316 stainless steel are apparently not attacked by sulfate liquor. They are, however, slightly attacked by the vapors driven off during the cooking cycle.

3. Carbon brick is completely immune to attack by both sulfate and neutral sulfite liquors. The mortar joints, however, are subject to attack, and thus must be inspected and repaired at frequent intervals to prevent damage to the steel shell of the vessel.

4. Small areas of stainless steel weld overlay accelerate the corrosion of the plain carbon steel in areas immediately adjacent, requiring continued extension of the overlay.

Received Oct. 30, 1959, presented at the 14th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Piittsburgh, Pa., Oct. 12–15, 1959.

Extensible Paper Machinery

CHARLES E. HILL

Clupak is the tradename for a unique new paper with the appearance of a natural sheet whose most striking feature is an exceptionally high degree of controlled stretch. This stretch, in combination with a high tensile strength, imparts to extensible paper a toughness which can be three or more times that of regular paper. It is principally this added toughness which makes Clupak paper superior to regular paper for applications, such as multiwall sacks, which involve shock loads. Toughness is the best way to evaluate extensible paper since neither stretch nor tensile alone tells the full story (*1*, *2*). Toughness is a measure of work, or the ability of the paper to absorb energy before rupturing. Mathematically, it is the area under the stress strain curve up to the breaking point expressed as in. lb. per 100 sq. in. of surface area. Figure 1 shows typical machine direction (MD) stress strain curves for 50 lb. multiwall sack (MWS) paper. It will be noted that stretch has been increased about 500%. At the same time, machine direction tensile has decreased about 25%. Figure 2 shows what has happened to the cross direction (CD) properties of the same 50 lb. MWS sheets. Stretch and toughness have increased, but not nearly to the degree of improvement in MD properties (*3*). It is an inherent characteristic of the extensible process that machine direction stretch is accurately controllable, whereas cross direction stretch is not.

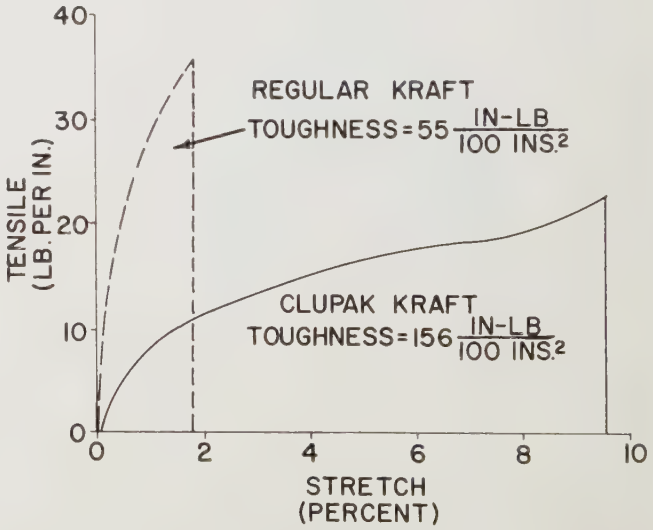

Fig. 1. Machine direction—50 basis weight

Some other interesting characteristic properties of extensible paper are shown in Fig. 3. In the Clupak paper process, the fibers are compacted and reoriented without

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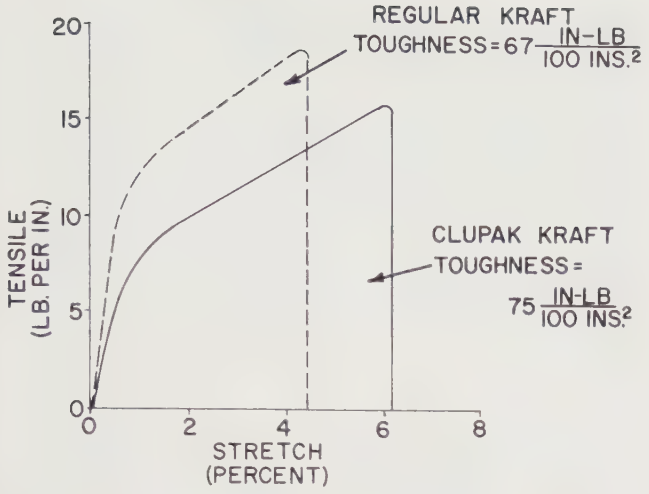

Fig. 2. Cross-machine direction—50 basis weight

moving out of their original planes. This results in a denser sheet than regular kraft. When the stretch is removed from Clupak paper, the caliper is not substantially reduced and actually increases in many cases. This is a fundamental difference between Clupak paper and crepe paper and, in fact, is noted in the basic extensible paper patent (4).

USES OF CLUPAK

Before going into the actual details of manufacture, it might be interesting to consider some of the uses of Clupak paper. Figure 4 shows a few of the many applications in the multiwall bag field. All of these are actual field tested constructions. Here, both the added toughness and added stretch are valuable. Other applications are principally concerned with the high stretch properties. An outstanding example is in the formation of phenolic resin laminated materials where the paper base often must be formed around corners after lamination. Clupak paper has also been successfully wet and dry waxed, polyethylene coated, asphalt laminated, clay coated, and supercalendered; in short, about every surface treatment to which regular papers are subjected.

HOW CLUPAK IS MADE

Fundamentally, the manufacture of Clupak paper entails compacting of paper at the point in the manufacturing process where only part of the hydrogen bonds have been formed. The present extensible paper machine is based on the mechanism of using an elastic medium, a means of stretching the

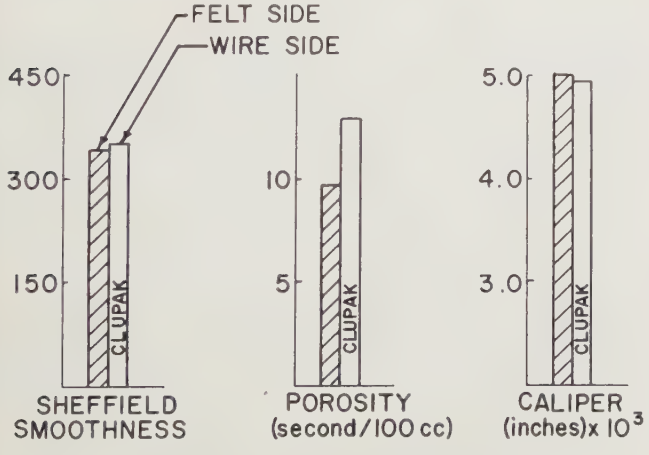

Fig. 3. Typical properties—50 basis weight

PRODUCT	WT.	TYPE	REGULAR CONSTRUCTION		CLUPAK CONSTRUCTION		BASIS WT. REDUCTION %
POTATOES	50	POM	3/50	(150)	2/40, 1/50	(130)	8.7
CLAY	50	PV	2/40, 1/50	(130)	2/60	(120)	9.1
FERTILIZER	80	SV	1/90 AL, 2/60	(210)	1/100 AL, 1/40, 1/50	(190)	9.5
SODA ASH	100	SOM	5/50, 1/60	(310)	2/50, 3/60	(280)	9.7
CEMENT	94	PV	2/40, 2/50	(180)	2/50, 1/60	(160)	11.1
CEMENT	70	PV	4/40	(160)	1/40, 2/50	(140)	12.5
SAND	100	SV	3/40, 1/60, 1/50	(230)	2/40, 2/50	(180)	21.7

Fig. 4. Typical Clupak paper sack constructions

medium longitudinally so that the surface is elongated, pressing a paper web of suitable moisture content against this surface, and allowing the medium to contract, thus causing the paper web to shrink with it.

Figure 5 shows the essential parts of a machine to carry out this sequence of events. The nip bar and the drier form a passage less than the normal blanket thickness. Rubber is essentially incompressible, which means that the only way for the same volume to pass through a smaller area is for the rubber to speed up. The rubber blanket accelerates as it curves around the nip bar, further accelerates as it anticipates the restricted nip and speeds up to get through. After passing through the nip, the blanket relaxes toward its original length, and the surface speed is further slowed due to the reverse curve of the extensible paper drier.

Wet paper is laid on the stretched blanket as close to the nip point as practical. The paper is held tightly to the blanket to which it adheres by pressing against the drier, and is thus forced to shrink as the rubber blanket shrinks from its expanded length at the nip to its contracted length around the drier.

Machine direction stretch of over 100% has been achieved in the laboratory by this method. On the machine, 20% stretch has been achieved and higher would be possible. While machine direction stretch increases substantially, there is a limited concurrent increase in CD stretch and toughness.

HISTORY OF DEVELOPMENT

The process described is similar in principle to Sanforized, a process for cloth. It was Sanford Cluett, inventor of this textile process, who approached West Virginia Pulp & Paper Co. in 1954 with his process for producing extensible paper.

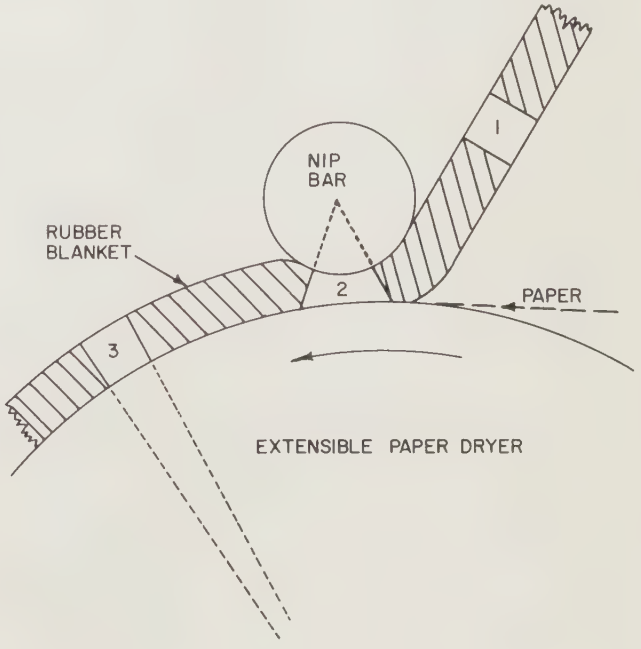

Fig. 5. Diagramatic view of blanket action

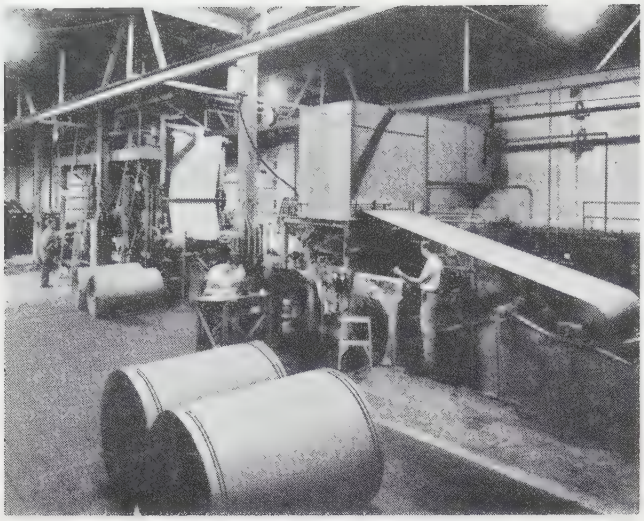

Fig. 6. 60-In. pilot machine

After preliminary investigation, an agreement was entered into with Cluett Peabody and Co. to undertake development of the process. By mid 1955, bench scale testing was complete and a 60-in. pilot plant was constructed adjacent to the kraft mill in Charleston, S. C. Figure 6 shows the Morrison Machine Co. unit installed in the pilot plant.

In mid 1957, a decision was made to install a commercial unit on No. 3 machine which was then under construction. This is a 264-in. Beloit machine designed to produce unbleached kraft bag papers at 2500 f.p.m. The mechanical details of this machine have already been published (*5*). The extensible unit actually went into commercial production on Dec. 26, 1957. Since that time, many additional installations have been licensed by Clupak, Inc. West Virginia's second unit went into operation January, 1959. The first competitive installation at International Paper Co., Camden, Ark., went into operation May, 1959.

The general arrangement of no. 3 machine extensible unit is shown in Figure 7. We will now discuss the design features of this installation in some detail.

Nip Roll Arrangement

The nip bar on this machine is $6^1/_2$-in. diameter. A larger bar would be desirable from the point of view of deflection; however, any attempt to use a larger bar is self-defeating. The amount of shrinkage is largely determined by the reduction of area at the nip. Due to a wider nip, larger bars require heavier static loading to achieve the same reduction of area. Total loadings quickly get out of hand.

The nip bar arrangement, as now used, is supported with nine pairs of backing shoes. Nip pressure is independently adjustable at each backing shoe. The nip bar is stationary and flooded with water, which is an excellent lubricant for rubber.

The original extensible unit had a rotating nip roll backed by nine pairs of 12-in. diameter rollers. This roll arrangement was quickly found to be unnecessary and was soon replaced with the simple bearing and bar arrangement.

When the first unit was installed, it was thought that it might be necessary to load against fixed stops to maintain a positive nip opening and to prevent vibration. This was found to be unnecessary and the equipment now operates with floating load control.

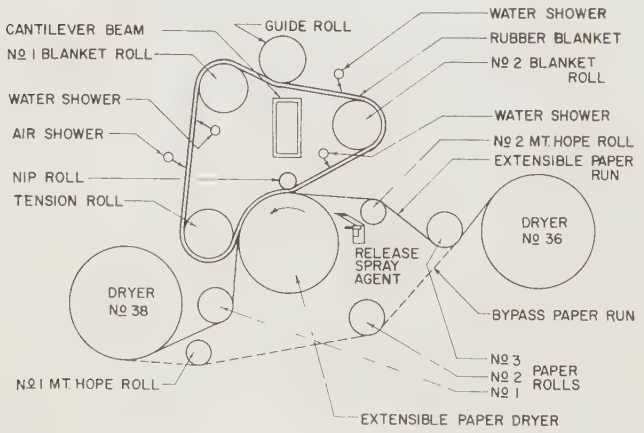

Fig. 7. Typical extensible paper machine arrangement

Steam Drum

The main drum is 48-in. diameter, chrome plated. It is steam heated with a maximum design pressure of 150 p.s.i.g.

It is quite important that paper does not stick to the drum. The drum is traveling at approximately the speed of the blanket at the nip, therefore if the paper adheres to the drum, it will not be compacted as the blanket shrinks relative to the drum after leaving the nip. To assure no sticking, the drum is heated with 60 to 70 p.s.i.g. steam, which evaporates moisture from the sheet forming a layer of steam which acts as a lubricant between the sheet and the drier. In addition, a release agent is sprayed on the sheet as it enters the nip to further guard against sticking.

Blanket Tension Arrangement

Accurate control of tension is important. The tension must be high enough to hold the belt tight against the steam drum while the paper is being compacted. Blanket tension, which is applied through a diaphragm and lever arrangement, is normally around 30 to 35 lb per in.

A certain amount of roughness is acceptable in multiwall sack paper, but it is possible to make Clupak paper which is actually smoother than regular kraft. An interesting sidelight is the fact that the wire side of Clupak paper is as smooth as the felt side of regular paper. The reason is the polishing action of the steam drier as the paper compacts against it. It would be entirely feasible to build an extensible unit with the felt side against the steam drum, but this would place the blanket on the underside of the drum. In the event of a break, paper could pile up in the nip and damage the blanket. Placing the blanket on the side of the drum would normally not be feasible due to space limitations. The arrangement used at Charleston can be installed by removing four driers, which is the same amount of space normally occupied by a size press.

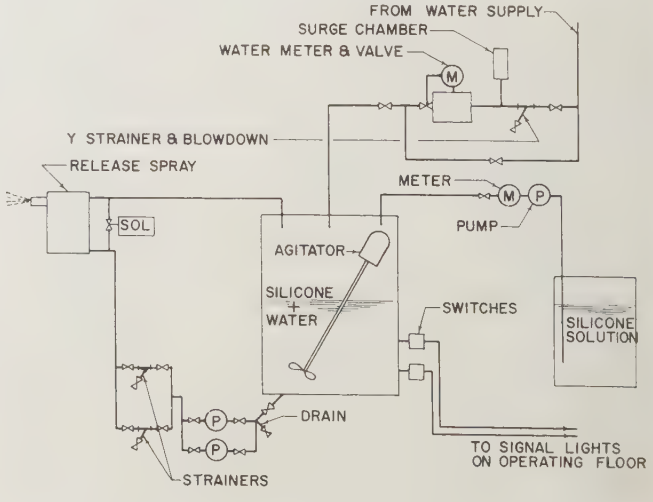

Fig. 8. Release agent piping diagram

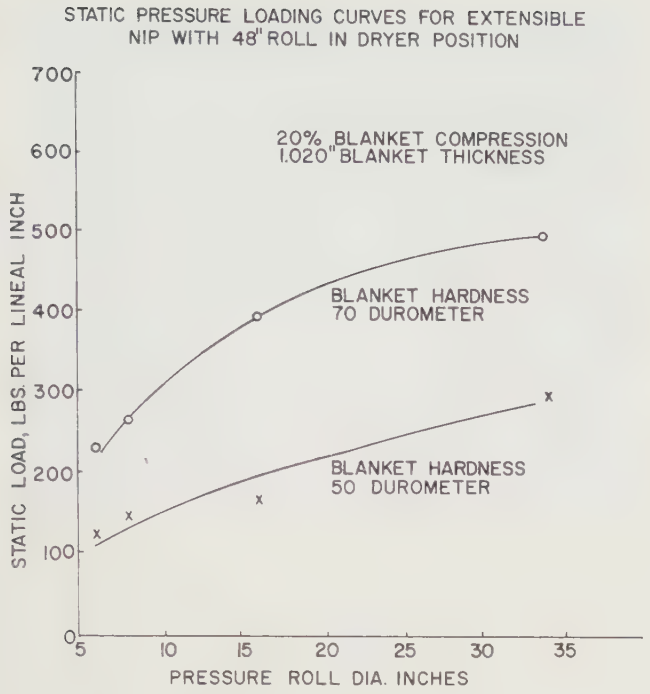

Fig. 9. Static pressure loading curves for extensible nip with 48-in. roll in drier position

Guiding

The guides used on the extensible units are similar to wet felt guides except for size. As with other guides, it is important to have a good wrap. On the no. 2 unit, the guide roll has a good wrap and accurate tracking of the blanket is no problem.

Originally, some difficulty was experienced on no. 3 machine during the unstable conditions which occur when threading. Operating experience has corrected this.

Water at the nip of the guide roll will act as a lubricant and drastically reduce the guiding efficiency. An air shower is used to scour off any moisture on the blanket before it passes the guide.

Showers

The nip bar is stationary and it is necessary to keep it well lubricated with water. Several internal showers are used for this purpose. If the showers should fail, the frictional heat developed would quickly soften and destroy the blanket. We have lost two blankets because of this. Since then, we added additional showers on independent supply systems.

Fig. 10. Traveling belt grinder

Blanket cooling showers and nip lubricating showers are used during a break. The curing temperature of the blanket is 260 to 270°F., so these showers are quite important to prevent severe oxidation where the blanket contacts the hot drum. Edge cooling showers are used continuously to prevent oxidation and edge cracking where the rubber is not covered by paper.

In addition to heating the drum, a release agent is also required to assure the paper compacts on the blanket and does not stick to the drum. Figure 8 shows the essential elements of the equipment used to dilute the release agent to showering consistency. This mixture is pumped to air atomizing spray heads which are under the control of the back tender. Originally the showers were open; however, they are now enclosed in a box which fits closely to the steam drum. The excess spray is collected and returned to the system. Since enclosing the spray, we have noted a reduction of over 50% in release agent consumption.

Drive

Number 3 machine is equipped with a Beloit differential drive. The draw across the extensible unit is approximately equal to the stretch in the sheet. Provision must also be made for the production of regular kraft. The standard PIV controls do not permit sufficient draw range for these conditions, therefore, the differential units at the extensible unit and following sections are equipped with oilgear controls.

The draw between the unit and after drying section is quite important, as it is very easy to pull all of the stretch back out of the wet compacted sheet.

After no. 3 machine had been in operation a short time, it became apparent that the operators required a simple and accurate indication of draw, or stretch in this case. Potter Aeronautical Co. digital speed indicating equipment was installed on the extensible unit and the reel. Later, this equipment was installed on all sections, permitting the operators to read absolute speed of any section, or the ratio of speeds between any two sections.

Number 2 machine is belt driven from a basement lineshaft. The extensible unit, and the after lineshaft driving the 3rd drier section, calender and reel, are driven by differential drives equipped with oilgear controls.

On the original unit, the only drive was on the 48-in. drum. There was some difficulty with slippage between the drum and blanket when starting up and threading. It was thought that a helper drive on the blanket would minimize this problem. As the crew gained experience, however, they found it to be almost as easy to start up without the helper drive. Later installations at other mills do not have helper drives.

Rubber Blanket

The amount of compaction at a given nip setting is determined by the hardness of the rubber blanket, Fig. 9. The softer blanket gives higher compaction. On the other hand, a harder blanket gives a smoother sheet and has better life. Increasing thickness has a similar effect as increasing softness.

The first blanket used had a 55 durometer (107 P&J). This was later changed to 50 durometer (123 P&J), and 45 duro (146 P&J) has also been tried; but we have about standardized on 50 as being optimum.

Number 3 machine was initially equipped with a full-width roll grinder. Because of deflection and chattering of the grinding roll, it was impossible to do a good job in a reasonable length of time, so it was replaced with a traveling belt grinder, Fig. 10.

The blankets are ground dry with a 10-in. wide belt. The standard width on machines now being built is 4 in. The blanket crawl drive operates at 42 f.p.m.

Blankets are ground every wire change, which usually works out to around 200 operating hours. Surface cracks begin to appear on the edges at about 250 hr. At this point, the

blanket must be ground because the cracks propagate rapidly. A minimum of 0.030 in. of material is removed at each grinding. One pass takes about 35 min. and two or three passes are minimum for a smooth surface. Actual practice is to take as many additional passes as wire shut down time will permit. The blanket should be ground cold, otherwise it is impossible to get a uniform surface.

Initial cost projections were based on a blanket life of 500 hr. Improvements in blanket construction and operating practice are such that we now expect to exceed a life of 2000 hr.

We feel that the blanket will completely lose its usefulness when reduced to about $^1/_2$-in. thickness. So far, we have always had to remove a blanket for other reasons long before reaching this point.

Blankets for no. 3 machine cost about $12,000 and take about 6 hr. to replace, so there is good reason to seek longer life.

The blankets are 25 ft. inside circumference. A $1^1/_8$ by 256-in. wide blanket for our no. 3 machine weighs agout 4000 lb. Blankets are draped over a large metal pipe and shipped in a wooden box. Blankets should be stored with the same precautions taken with a rubber covered roll. The manufacturer recommends periodic rotation, but we have not found this to be necessary on blankets stored up to 6 months. We normally operate with two spares on hand and a third in the manufacturer's finished inventory. Changing a blanket is similar in principle to putting on a fourdrinier wire. The nip bar and loading arrangement plus two of the inside blanket rolls are permanently mounted to a cantilever beam. The tension roll is also hung from this beam during blanket change.

The endless blanket is draped on a special frame, Fig. 11, using the two inside shipping poles. The blanket is then carried by crane over the cantilevered beam, Fig. 12.

Location of Extensible Unit

The moisture content at the extensible unit is extremely important in determining the amount of stretch and surface character of the sheet. At moisture contents of 35% (wet basis) and above, very smooth sheets are produced. The stretch is easily pulled out of such a wet sheet in the following draws, hence more stretch must be imparted at the unit in order to compensate. The wet sheet also tends to stick to the drum, which hinders compaction and necessitates consumption of more release agent.

Moisture contents in the 25 to 30% range produce high stretch with a minimum amount of nip compression and release agent consumption. It is very difficult, however, to produce a sheet which is not fairly rough.

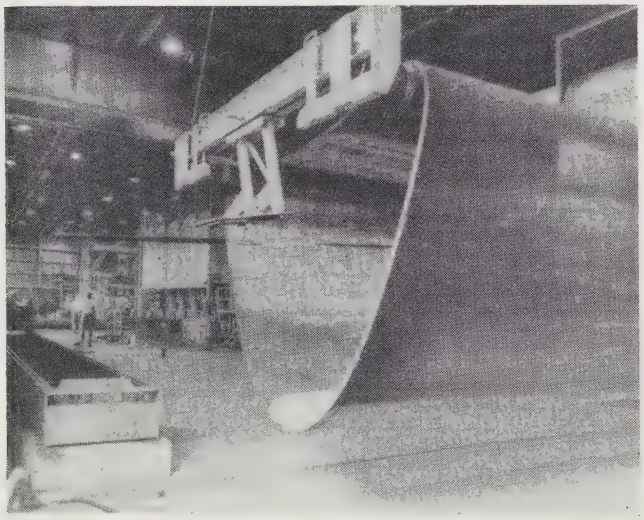

Fig. 11. Blanket draped on special frame

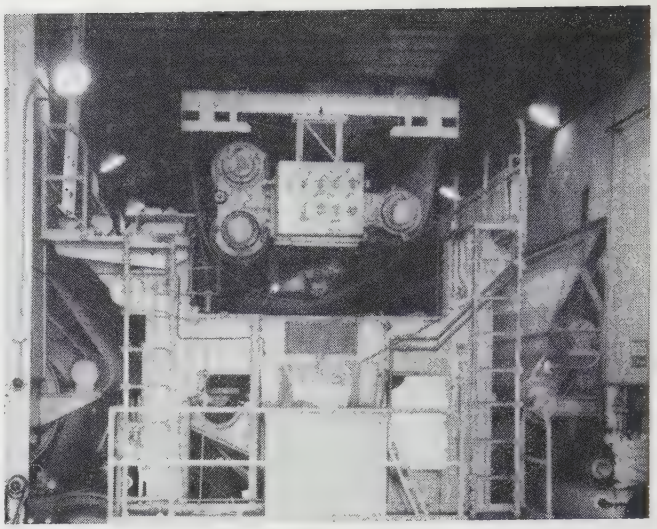

Fig. 12. Extensible unit with main beam cantilevered

It was initially thought that an optimum moisture content would be about 35%. This is also the sheet condition in the area of the size press, when the press is not in use. Our no. 3 unit was actually installed in the space originally provided for a size press.

Under actual operating conditions, it has sometimes been found necessary to operate above the 35% area in order to make an acceptably smooth sheet. This increase in moisture level has left us somewhat short of after drier capacity. In an effort to restore drying balance, we are now evaluating hot air drying hoods on our no. 2 machine.

Operation

There have been few changes either in operating procedure or stock preparation. The backtender is responsible for the extensible unit; no additional personnel have been added.

Threading the unit requires some changes in technique, which is to go quickly from a narrow tail through the machine to a full width sheet. Running a partially widened leader through the unit tends to guide the blanket to the back of the machine.

Cross machine moisture profile is of primary concern to the machine tender. Variations in moisture lead to variation in stretch and roughness. Dry edges are a continuous problem and are the main reason why moisture levels must be held higher on light weight grades than on heavier weights.

The calendering operation is usually skipped since we are producing multiwall sack, grocery bag, and other grades requiring a rough finish.

Operation of the winder is completely standard. No measurable stretch is lost during this operation under normal tensions.

CONCLUSION

Clupak paper is a fundamentally new paper which is finding new applications almost daily. The process is deceptively simple when compared to the massive equipment actually required to carry it out.

The equipment described here is doing a commendable job of producing huge tonnages of Clupak paper. In any field, early technological advances usually come rapidly, and there is no doubt that we shall see the same rapid improvement in extensible paper machinery.

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Received Oct. 30, 1959. Presented at the 14th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Pittsburgh, Pa., Oct. 12–15, 1959.

Extrusion Coating of Polypropylene on Paper

W. J. G. McCULLOCH and A. J. WARD, JR.

The polyolefin extrusion coating market is predicted to grow to 100 × 10^6 lb. per yr. by 1963. By virtue of polypropylene's superior barrier properties to conventional polyethylene, polypropylene appears as a strong candidate to capture a substantial portion of this expanding market. Polypropylene's property advantages over conventional polyethylene as an extrusion coating material are: improved oil and grease resistance, improved-heat resistance, lower moisture vapor transmission rate, superior abrasion resistance, superior appearance and gloss, superior surface hardness, greater stiffness and strength, higher pound-volume yield, and lack of environmental stress cracking.

These superior properties are of immediate practical interest to potential end-users if polypropylene can be satisfactorily processed in conventional type equipment. It is the intent of this article to discuss the type of equipment and certain processing conditions which are required to obtain successful thin coatings of Escon polypropylene at acceptable rates.

Results were obtained on a laboratory $2^1/_2$-in. diam. extruder with an L/D ratio of 16/1. The accompanying web had a nominal width of 24 in. Coating weights were obtained at the maximum speed which produced a coating of acceptable quality. Coating thicknesses were measured in pounds per 3000 sq. ft. ream. A 0.001-in. coating of polypropylene is equivalent to 14 lb. per ream.

PROPERTIES OF POLYPROPYLENE

In reviewing the physical properties of polypropylene, a comparison has been made with the most widely used extrusion coating resin, conventional polyethylene. The pertinent physical data in Table I clearly reveal the improved temperature resistance, strength, hardness, stiffness, and lack of environmental stress cracking with polypropylene.

In addition to its outstanding physical properties, polypropylene exhibits a good balance of excellent barrier properties. In Table II it can be seen that polypropylene has lower moisture vapor transmission and gas permeability rates than does conventional polyethylene. Oil resistance is also good—a fourfold improvement over that exhibited by conventional polyethylene. The effect of polypropylene density (crystallinity) on oil resistance is shown in Fig. 1 and, as expected, oil resistance increases with density.

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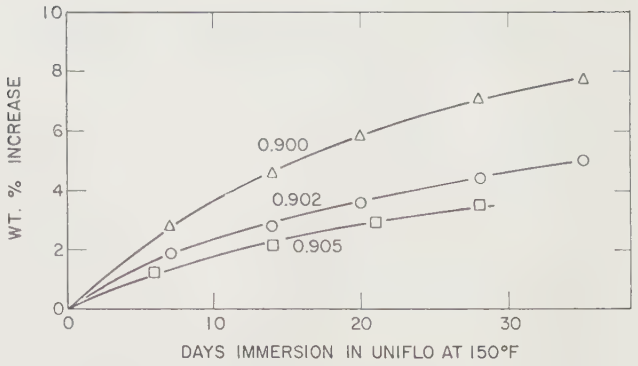

Fig. 1. Effect of polypropylene density on oil resistance

Uniflo oil immersion at 150°F., ASTM D 543–56 T.

Some preliminary adhesion strengths have been determined by the Perkins-Southwick bond tester. Figure 2 shows the free film burst strength of nylon, conventional polyethylene, and polypropylene. As one might expect, polypropylene gives intermediate values. The data presented in Fig. 3 show the adhesion and ultimate burst strengths of polypropylene-coated paper. The adhesion strength was determined by placing the coated side up over the orifice of the bond tester while the ultimate burst strength was determined

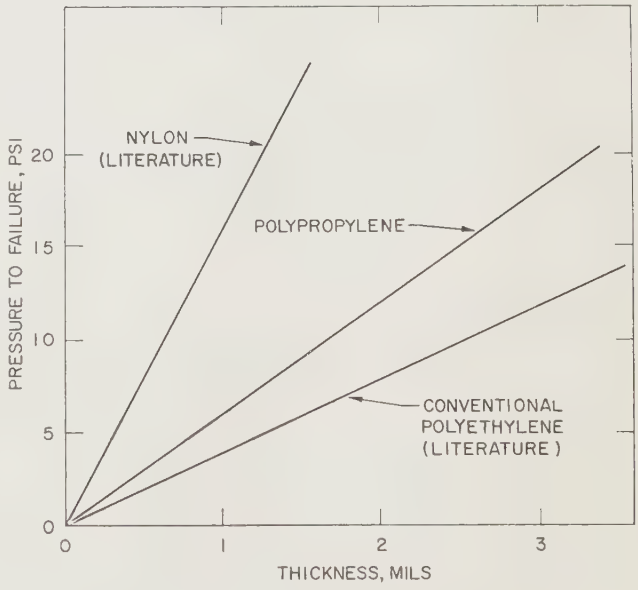

Fig. 2. Burst strength of free film

with the coated side down. These data indicate that, under the test conditions, satisfactory adhesions result at coating thicknesses of 0.0015 in. and greater. In addition, effective heat seals have been demonstrated on laboratory sealing equipment.

Table I. Physical Properties of Escon Polypropylene

	Method	*Polypropylene*	*Conventional polyethylene*
Density, 73°F.	ASTM D 1505–57 T	0.90	0.92
Heat distortion temperature, °F. (66 p.s.i.)	ASTM D 648–56	190	105–115
Yield strength, 73°F., p.s.i., 2 in./min.	ASTM D 638–56 T	5000	1800–2200
Hardness, 73°F.			
Rockwell R	ASTM D 785–51	80	25–35
Shore D	ASTM D 676–58 T	72	48–52
Environmental stress cracking in 100% Igepal CD-630, hr. to 50% failure	Bell laboratories	>2000 (no failures)	<1
Stiffness in flexure, p.s.i.	ASTM D 747–58 T	140,000	25,000

Table II. Barrier Properties of Escon Polypropylene

	Polypropylene	*Conventional polyethylene*
Moisture vapor transmission rate,[a] (g./24 hr./100 sq. in./0.001 in.) (General Foods method)	0.40 to 0.50	1.4
Gas permeability,[a] (cc./24 hr./100 sq. in./0.001 in.) 77°F.		
O_2	97	550
CO_2	280	2900
Oil resistance, wt. increase, % (Uniflo oil/28 days/150°F.) (ASTM D 543-56 T)	3.5 to 7	19

[a] Film samples.

PROCESSING CHARACTERISTICS OF POLYPROPYLENE

Processing data were obtained on a laboratory $2^1/_2$-in. diam. extruder with an L/D ratio of 16/1 and an accompanying web of 24-in. width. The substrate coated in this study was 50 lb. natural kraft paper. The main emphasis of this study was placed on the effect of certain design and operating variables on the melt drawdown characteristics of polypropylene. These results should not be regarded as the optimum

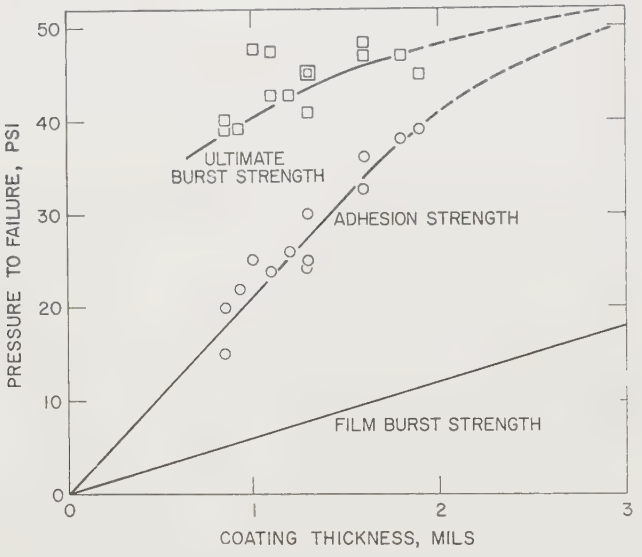

Fig. 3. Adhesion of Escon coated paper

obtainable in the extrusion coating of polypropylene; but rather as a processing guide to those converters conducting initial coating programs with polypropylene.

The principal restricting factor regarding the drawdown of polypropylene has been surge or loss of control of coating gage. This effect can be minimized greatly with the proper choice of operating conditions, such as die position and chill roll temperature, and with slight equipment modifications, such as die design. These special techniques are necessitated by the difference in rheological properties between polypropylene and conventional polyethylene. It is important to note, however, that in free film extrusion, speeds well in excess of 200 f.p.m. have been obtained with polypropylene using conventional equipment.

Table III. Effect of Die Design on Coating Speed[a]

Die design	*Coating speed, f.p.m.*	*Coating weight, lb./ream*	*Adaptor resin pressure, p.s.i.g.*
Conventional PE $^1/_{16}$ in. land	25	50	100
Extended jaw $^3/_4$ in. land	80	28	200
Tear drop hanger 1 in. land	150	18–21	550

[a] Surge limited.

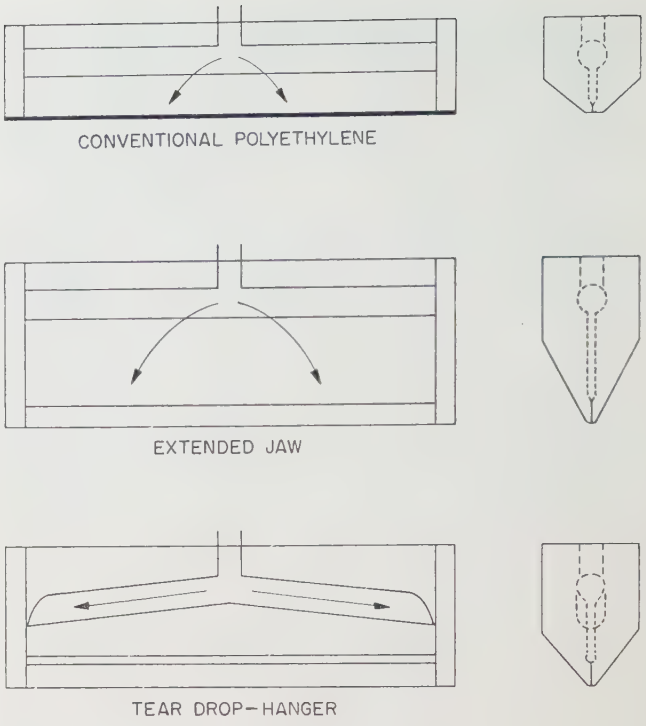

Fig. 4. Coating die designs

The processing variables studied and their effect on coating speed are described below.

Effect of Die Design on Coating Speed

Typical laboratory results obtained from the die designs studied are summarized in Table III. The dies are depicted in Fig. 4. These data show that the tear-drop hanger design type die has increased the coating speed of polypropylene to 150 f.p.m. The improved drawdown has resulted from the increased back pressure at the die as well as the internal design of the hanger type die which results in a uniform flow profile across the die. The design of the manifold of the conventional polyethylene die appears unable to perform this effect in extrusion coating of polypropylene and a surge pattern emanating at the center results. This surge is also due in part to the inability of the short land of the conventional polyethylene die to convert all the elastic responses to viscous responses, which is required for successful extrusions.

The optimum resin temperature range is between 550 and 570°F. resulting in satisfactory adhesion at coatings of 0.0015 in. or greater.

Effect of Chill Roll Temperature on Coating Speed

Various chill roll temperatures were studied to determine their effect on coating speed. The results are summarized in Table IV. These data show that with high density poly-

Table IV. Effect of Chill Roll Temperature on Coating Speed

Chill roll temp., °F.	*Resin density, 73°F. g/cc.*	*Coating speed, f.p.m.*	*Coating weight, lb./ream*	*Curl*
100	High density	95	33	No
135	(>0.901)	100	32	Yes
105	High density	110	29	No
180	(>0.901)	140	22	Yes
110	Low density	135	17	No
150	(0.895)	130	17	Very slight

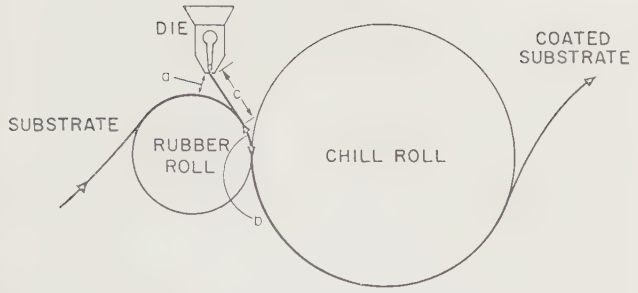

Fig. 5. Critical die position dimensions in extrusion coating

propylene coating speed is improved appreciably when using high chill roll temperatures. Additionally, adhesion and coating gloss are also improved. In general, temperatures greater than 150°F. are required. Chill roll temperature, however, has no effect on the drawdown of low density polypropylene. Furthermore, low density resins, under comparable conditions, extrusion coat at faster rates than do high density resins, however it must be realized that these resins will have poorer barrier properties and lower stiffness values.

A disadvantage of high chill roll temperatures when using high density resins is the tendency for the resultant coating to curl. Low density resins do not exhibit this behavior.

Effect of Die Position on Coating Speed

Various die positions in relation to the nip were investigated and are described by the diagram given in Fig. 5.

The dimensions *a*, *b*, and *c* are defined as follows:

- *a* = vertical distance between die land and rubber roll (substrate) surface
- *b* = circumferential distance from nip to point at which extrudate contacts paper
- *c* = diagonal distance between die land and point at which extrudate contacts paper (actual film drawdown distance)

Typical laboratory results from one set of die positions (for example, the laminator is moved to the left in the above diagram and at the same vertical height) are given in Table V.

Table V. Effect of Die Position on Coating Speed

Die position			Coating speed,
a	*b*	*c*	*f.p.m.*
1/2	1 1/2	1 3/4	145
5/8	1 3/8	1 7/8	130
3/4	1	2	140
1	1	2 1/8	90
1 1/8	3/4	2 1/4	90
1 3/4	1/2	2 5/8	70

The optimum results from all sets of die positions studied are summarized below.

Die position dimension	*Optimum value, in.*
a	3/8 to 3/4
b	1 to 1 1/2
c	1 3/8 to 2

These data show that an optimum die position increases the coating speed of Escon polypropylene from 70 to 140 f.p.m. an improvement of 100%. Poor die positions are located directly over the nip, giving large values of *a* and *c* and small values of *b*. This combination leads to a heavy surge and low speeds. Optimum die positions are further removed from the nip and are located over the rubber roll, resulting in small values of *a*, medium values of *c*, and generally fairly large values of *b*. This combination results in decreased extrudate heat losses, very light surge, and high coating speeds. Polypropylene, are relatively highly crystalline material, has a tendency to orient during drawdown. To retard this tendency to orient, minimum die blade openings and hence minimum drawdown would be desirable.

Table VI. Effect of Screw Speed on Coating Speed

Screw speed, r.p.m.	*Coating speed, f.p.m.*	*Coating weight, lb./ream*
	Tear Drop Hanger Die	
30	65	17
75	140	22
	Extended Jaw Die	
20	28	19
40	32	37
75	60	34

A difficulty encountered with die positions having small values of *a*, is the entrapment of air bubbles between the film and substrate which appear as lines of thin areas in the machine direction of the coating. We believe that air is drawn in by the fast moving substrate and is trapped by the film when using relatively long film contact distances on the substrate before the nip. The resultant rather broad lies seen on the coating appear to be related to die surface protrusions. Preliminary studies conducted to date to prevent air entrapment and to streamline the die surface have resulted in increased processing rates (to 160 f.p.m.) before limiting surge takes place.

Effect of Screw Speed on Coating Speed

When polypropylene is drawn-down over short air gaps, coating speed increases with increasing screw speed as shown by the data presented in Table VI. High extrusion rates increase the back pressure at the die which appears to be required for thin coatings of polypropylene.

Effect of Polypropylene Properties on Coating Speed

Studies were conducted to determine the optimum grade of Escon polypropylene for extrusion coatings. The data are given in Table VII.

The data in Table VII (Part 1) show that with polypropylene having a density greater than 0.898, coating speed increases as the melt index increases from 6 to 26 (measured at 482°F. (250°C.)). The optimum melt index appears to be about 15 to 20. The data shown in Table VII (Part 2) indicate that at near optimum melt index values low crystallinity resins (density 0.895 to 0.897) extrusion coat at higher speeds than do highly crystalline resins. However, certain barrier properties must be sacrificed if low density resins are to be used, namely, grease and hydrocarbon resistance.

Table VII. Effect of Polypropylene Properties on Coating Speed

Density, 73°F., g./cc.	*Melt index g./10 min., 482°F.*	*Coating speed, f.p.m.*
	Extended Jaw Die (Part 1)	
0.898	6	<50
0.900	9	65
0.902	15	75
0.901	26	80
	Tear Drop-Hanger Die (Part 2)	
0.895	17	135
0.897	13	140
0.901	26	105
0.906	26	110

Table VIII. Effect of Die Opening on Coating Speed

Die opening, in.	Die opening, mils	Pressure, p.s.i.g.	Coating speed, f.p.m.	Coating weight, lb./ream	Output, lb./hr.
		Extended Jaw Die			
0.018	18	120	55	37	95
0.002	2	260	55	37	88
		Tear Drop-Hanger Die			
0.023	23	480	140	20	80
0.015	15	550	145	14	81
0.011	11	600	150	16	82

Effect of Die Opening on Coating Speeds

As shown by the data given in Table VIII, die openings between 0.002 and 0.023 in. have no appreciable effect on coating speed. However, since Escon requires a minimum drawdown, the thinner openings are recommended, with a die opening of 0.015 in. preferred.

Effect of Barrel Temperature on Coating Speed

The two heating zones of the extruder barrel were varied to determine the effect on resin mixing and resultant drawdown of Escon. The results are given in Table IX. These data

Table IX. Effect of Barrel Temperature on Coating Speed

Barrel temperatures, °F.		Resin temperature, °F.		Pressure,	Coating speed,
Zone 1	Zone 2	Level	Range	p.s.i.g.	f.p.m.
400	660	560	3	480	120
580	580	560	3	480	135

show that a uniform temperature on the barrel (nongradient) has a slightly beneficial effect on drawdown. With a relatively short extruder (L/D ratio of 16/1) the high zone 1 (next to hopper) temperature allows a lower zone 2 temperature which in turn is only slightly in excess of the resin temperature employed.

Effect of Variables on Increasing the Melt Capacity of the Extruder

Effect of Screen Pack on Resin Temperature and Coating Speed. The results given in Table X show that polypropylene extrusion coatings are only slightly affected by increasing the screen pack from 40 to 200 mesh. However, the melt capacity of the extruder has been increased as evidenced by the higher and more uniform resin temperatures. The output has been reduced, as expected.

Table X. Effect of Screen Pack on Resin Temperature and Coating Speed

Screen pack, mesh	Resin temperature, °F. Level	Range	Output, lb./hr.	Coating speed, f.p.m.
	Extended Jaw Die			
40-80-40	492	32	..	65
40-80-120-2(200)-80	519	27	..	60
	Tear Drop-Hanger Die			
40	540	..	83	125
40-80-120-2(200)-80	560	..	78	115

Effect of Screw Design on Resin Temperature and Coating Speed. The screw design employed for polypropylene extrusion coating studies has been a modified nylon metering type. The metering section was varied in depth to determine the effect on resin temperature and coating speed. The data describing the screw-types used are given in Table XI.

Table XI

	Channel depth, in. Feed	Compression	Metering	Depth compression ratio
No. 1	0.491	0.470	0.103	4.8
No. 2	0.320	0.301	0.075	4.3

As shown by the data in Table XII, the shallow channel screw (No. 2) in conjunction with a 200-mesh screen pack, has increased the resin temperature markedly and has reduced the resin temperature range to 10°F. under the conditions of test. However, no effect on coating speed was noticed. In addition, the output is reduced by 20% when

Table XII. Effect of Screw Design on Resin Temperature and Coating Speed

Extended Jaw Die

Screw type	Screen pack, mesh	Resin temperature, °F. Level	Range	Output, lb./hr.	Coating speed, f.p.m.
No. 1	40-80-40	500	20	102	50
No. 2	40-80-120-2(200)-80	575	10	82	52

using a shallower channel screw and a heavy mesh screen pack. These data suggest that extruders with longer barrels (L/D ratio 20/1 to 24/1) than that used for this study should be employed for polypropylene in order to acquire high outputs of homogeneous and high temperature extrudates.

Received Sept. 16, 1959. Presented at the 14th Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, held in Chicago, Ill., Sept. 21–23, 1959.

Plastic Coated Papers Versus Films in Food Packaging

D. G. MACDONALD and M. L. DOWNS

Today's food processing industry has tremendously increased its emphasis on the food package. With the trend toward automation, a packaging material must meet stringent requirements in three distinct areas; protection, machinability, and appearance. Furthermore, since it is not uncommon to find a package costing more than its contents, these requirements must be met by the most economical means.

This study is based on the most popular flexible packaging materials in use today, namely paper, polyethylene, wax, and foil. Although there are many factors involved, the two which most often determine the acceptability of the material are moisture vapor transmission (MVT) and stress-strain relationships. We have, therefore, studied the subject materials on these two qualities, with special regard to their use on automatic packaging equipment.

PROTECTION

The protective properties of a package must meet both chemical and physical requirements. The physical strength must frequently be sufficient to carry the weight of the contents without additional support, resist puncturing by the contents, resist tearing from external causes and remain unchanged by external and internal effects for many months.

In Table I, the last column entitled energy or work, may be taken as one index of available mechanical strength, as it measures the amount of work used to break the material under tensile stress.

It is obvious that unsupported polyethylene film is far and away superior to all paper laminates in this respect.

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Table I

	Material	Cost, $/1000 sq. in.	Nitrogen cc./100 sq. in./mm. Hg.	Lard, days	GFMVT, g./100 sq. in./24 hr.	Package tests	Energy, in.-lb.
1	Type I polyethylene film—0.001 in.	0.0153	180	30	1.40	0.67	19.68
2	Type I polyethylene film—0.002 in.	0.0335	90	60	0.70	0.34	53.52
3	Type I polyethylene film—0.004 in.	0.0613	45	100	0.35	0.18	30.08
4	Type I polyethylene film—0.006 in.	0.0920	..	120+	0.20	0.11	54.24
5	Type I polyethylene film—0.010 in.	0.1535	..	120+	0.10	0.09	101.90
6	Type III polyethylene film—0.001 in.	0.0291	..	50	0.30	0.50	60.54
7	Type III polyethylene film—0.0015 in.	0.0389	..	120	0.20	0.13	25.70
8	25-lb. MB bleached kraft/5 lb. type I poly	0.041	..	10	2.00	1.80	0.81
9	25 lb. MG bleached kraft/10-lb. Type I poly	0.049	80	30	1.20	1.25	1.39
10	25-lb. MG bleached kraft/15-lb. Type I poly	0.060	61	45	0.90	0.91	0.56
11	25-lb. MG bleached kraft/20-lb. Type I poly	0.075	47	60	0.81	0.45	0.73
12	25-lb. MG bleached kraft/30-lb. Type I poly	0.093	29	90	0.65	0.38	1.66
13	25-lb. MG bleached kraft/45-lb. Type I poly	0.112	16	120+	0.42	0.21	0.87
14	25-lb. MG bleached kraft/10-lb. Type III poly	0.052	20	90	0.90	0.71	1.58
15	25-lb. MG bleached kraft/15-lb. Type III poly	0.063	15	120+	0.76	0.55	1.08
16	25-lb. MG bleached kraft/6-lb. poly/0.0003-in. foil/15-lb. poly	0.131	0	..	0.07	0.01	2.61
17	25-lb. MG bleached kraft/6-lb. poly/0.00035-in. foil/15-lb. poly	0.136	0	..	0.05	0.02	2.07
18	25-lb. MG bleached kraft/6-lb. poly/0.0005-in. foil/15-lb. poly	0.150	0	..	0.03	0	2.23
19	25-lb. MG bleached kraft/6-lb. poly/0.001-in. foil/15-lb. poly	0.190	0	..	0.001	0	3.09
20	1.5-lb. wax/25-lb. bleached cereal glassine/1.5-lb. wax	0.0158	..	N.R.	3.97	1.35	0.15
21	3.5-lb. wax/25-lb. bleached cereal glassine/3.5-lb. wax	0.0158	..	1	2.33	0.52	0.15
22	6.0-lb. wax/25-lb. bleached cereal glassine/6.0-lb. wax	0.0208	..	3	1.69	0.68	0.14
23	3.5-lb. wax/18-lb. S.C. kraft/5-lb. poly/3.5-lb. wax	0.020	..	20	0.36	0.20	0.51
24	3.5-lb. wax/18-lb. S.C. kraft/10-lb. poly/3.5-lb. wax	0.0292	..	90	0.14	0.33	0.59
25	18-lb. MG kraft/5-lb. poly/8-lb. wax/5-lb. poly/18-lb. MG kraft	0.0380	..	120+	0.07	0.49	1.24

Among the paper webs, increasing amounts of polyethylene give additional work absorption beyond the figures shown in Table I due to film layer stretch after paper failure.

Foil enhances the strength of the laminate considerably.

Concerning stability on aging, it has been our experience that unsupported films and paper webs will last at least as long as their chemical resistances in a uniform and unchanged condition. The only exceptions are wax grades, which block in temperatures over 120°F., and polyethylene film when it is exposed to ultraviolet radiation from direct sunlight; under this condition, film will lose most of its strength in 90 days.

The chemical requirements are usually defined as resistance to permeation of moisture vapor, gas, oils, and greases. Table I also tabulates data on MVT, nitrogen gas, and vegetable shortening permeation. The costs shown here are the industry list prices on unprinted webs in the maximum quantity bracket. Nitrogen permeation is expressed as cc. per 100 sq. in. per 24 hr. per mm. Hg and was run according to A.S.T.M. Method D-1434. Lard penetrations are expressed in days and were run by TAPPI Standard T-454 modified for shortening in place of sand-turpentine. The MVT tests are expressed in g. per 100 sq. in. per 24 hr. and were run by (1) the General Foods method at 100°F. 95% R.H., and (2) by packaging tests in heat sealed 6 × 4-in. pouches at 100°F., 95% R.H. Figure I graphically shows the results of the MVT studies in relation to cost.

The water vapor transmission tests are shown as areas within which a large number of flat and creased individual transmissions are found to fall. Note the logarithmic scale for transmissions. The scattering represents effects of coat and film variation, sheet roughness, poly density, as well as creasing effect. The creasing of samples was done by one method accepted by some food packers as presumably duplicating commercial pack experience. It incorporates a standard GFMVT disk with four line creases both in and across the machine direction, using full 180° creases, set at a pressure of 6 lb. per line-inch for 15 sec. These areas on Fig. 1, in effect, represent package performance so far as water vapor transmission is concerned.

Starting at the left at the low cost end, it is evident that light weight poly film gives more consistent protection per dollar than wax-coated cereal glassine only by virtue of the fact that creased tests on polyethylene are in the same range as the flat. Moving up the price scale, the indication is that light-weight grades produced by poly coating paper and subsequently waxing over the poly surface gives more protection per dollar than unsupported films. In the intermediate cost range, unsupported poly film gives more protection than the usual poly-paper grades at comparable cost. However, as will be pointed out later there are other mechanical considerations. The chart shows further that it is highly impractical from a cost standpoint to provide maximum water vapor transmission protection using heavy unsupported poly film and that paper-foil-poly combinations are a logical choice.

It is interesting to note that Type III polyethylene (high density) in both unsupported film and in combination with paper is considerably more economical protection than type I polyethylene. It is also interesting to compare poly-paper laminates to poly film at equal poly thicknesses; a given thickness of polyethylene has noticeably better permeability resistance in combination with paper substrates than as a free film, although theoretically the permeability resistance should decrease because of fiber wicking. There is no known explanation for this, but the evidence is certainly real.

MACHINABILITY

The machinability of a packaging material is best expressed by (1) its stress-strain relationship which is analogous to its uniformity and resistance to breakage during the machining operation (2) its ease of closure, which usually means speed and strength of heat seal, and (3) its rigidity or flexibility,

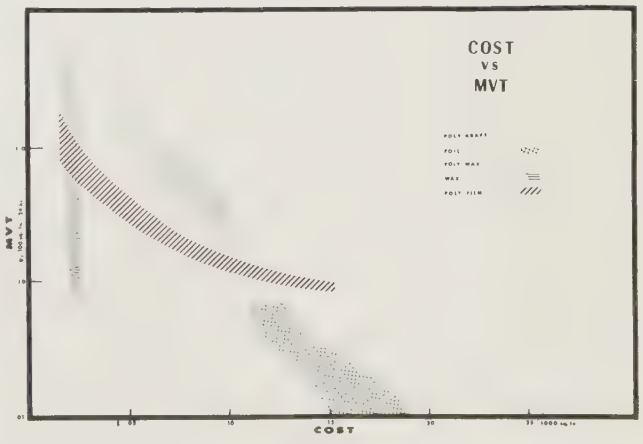

Fig. 1

Table II

	Material	Tensile at 1% stretch	Tensile at 10% stretch	Tensile at failure	Stretch at failure
1	Type I polyethylene film—0.001 in.	0.5	1.5	3.0	139.0
2	Type I polyethylene film—0.002 in.	0.5	2.0	4.5	252.0
3	Type I polyethylene film—0.004 in.	0.2	5.4	10.5	400.0
4	Type I polyethylene film—0.006 in.	0.4	9.0	14.8	540.0
5	Type I polyethylene film—0.010 in.	1.0	5.4	9.8	585.0
6	Type III polyethylene film—0.001 in.	1.8	4.6	5.0	497.0
7	Type III polyethylene film—0.0015 in.	0.3	6.3	5.0	485.0
8	25-lb. MG bleached kraft/5-lb. Type I poly	13.0	..	14.8	1.4
9	25-lb. MG bleached kraft/10-lb. Type I poly	12.8	..	18.5	2.0
10	25-lb. MG bleached kraft/15-lb. Type I poly	15.7	..	15.7	1.0
11	25-lb. MG bleached kraft/20-lb. Type I poly	13.2	..	14.2	1.4
12	25-lb. MG bleached kraft/30-lb. Type I poly	19.4	..	20.8	2.2
13	25-lb. MG bleached kraft/45-lb. Type I poly	11.8	..	16.0	1.6
14	25-lb. MG bleached kraft—10-lb. Type III poly	17.5	..	22.2	1.8
15	25-lb. MG bleached kraft/15-lb. Type III poly	18.8	..	23.1	1.9
16	25-lb. MG bleached kraft/6-lb. poly/0.0003-in. foil/15-lb. poly	13.7	..	24.1	2.8
17	25-lb. MG bleached kraft/6-lb. poly/0.00035-in. foil/15-lb. poly	16.0	..	23.8	2.4
18	25-lb. MG bleached kraft/6-lb. poly/0.0005-in. foil/15-lb. poly	21.5	..	28.9	1.9
19	25-lb. MG bleached kraft/6-lb. poly/0.001-in. foil/15-lb. poly	30.0	..	36.0	2.0
20	1.5-lb. wax/25-lb. bleached cereal glassine/1.5-lb. wax	..	..	9.0	0.5
21	3.5-lb. wax/25-lb. bleached cereal glassine/3.5-lb. wax	..	..	9.2	0.7
22	6.0-lb. wax/25-lb. bleached cereal glassine/6.0-lb. wax	..	..	8.7	0.5
23	3.5-lb. wax/18-lb. S.C. kraft/5-lb. poly/3.5-lb. wax	..	..	9.1	0.6
24	3.5-lb. wax/18-lb. S.C. kraft/10-lb. poly/3.5-lb. wax	10.7	..	11.4	1.2
25	18-lb. MG kraft/5-lb. poly/8-lb. wax/5-lb. poly/18-lb. MG kraft	24.0	..	26.4	1.2

according to the requirements of the particular packaging machine involved.

Your attention is now called to Table II which tabulates the stress-strain data of the materials studied. Please note especially the tensile load at 1% stretch. This is the limiting factor for automatic packaging materials for they must not exceed 2% stretch during the drawing cycle on almost all machines now in use. A stretch greater than 2% will cause sufficient deformation of the web to interrupt the packaging operation either by losing the web track, or missing a sealing station or, on printed webs, cause irregular cut-off from the electric eye control. On the other hand, it has been found that automatic packaging papers must have a minimum of 11 lb. per in. width tensile in the machine direction. This means that the machine draw exerts a force equivalent to something slightly less than 11 lb. per in. width, and it has been arbitrarily set at 10 lb. per in. width.

As can be seen in Fig. 2, there is a relatively limited area, defined by the dashed lines, on the stress-strain graph which indicates satisfactorily packaging machine operation. You will note, of course, that although practically all of the paper laminates meet this requirement, none of the unsupported film webs comply. This does not necessarily mean that unsupported film cannot be used on automatic packaging machines, because it is being used in a very limited way at the present time. However its speed of operation is necessarily greatly reduced because of its stress-strain relationship, and recovery time must be allowed for the web to compensate itself for the elongation it receives from the drawing stress. This is not true for paper laminates, which have practically no elongation.

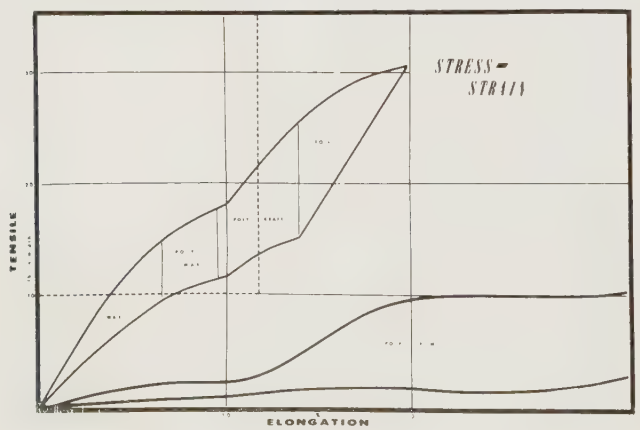

Fig. 2

As for the other requirements in machinability, heat sealing can be accomplished more easily with paper laminates due to the fact that the paper serves as a masking between the heat source and the polyethylene. Unsupported polyethylene film will stick to the heat source and cause rupturing of the package unless a hot wire method is utilized. However, since the hot wire method simultaneously cuts the film as it seals, it cannot always be used in the packaging operation.

As far as rigidity and flexibility are concerned, it is obvious that paper laminates are relatively rigid, and unsupported film is flexible. Some packaging machines require a certain amount of rigidity, and paper is the most economical means of obtaining it. Other machines require flexibility, and the paper must be highly plasticized for successful operation on them. Certainly no set rule can be made regarding this characteristic. However, in most food packaging, a more rigid package is usually desirable for appearance.

APPEARANCE

The matter of appearance is so completely subjective that virtually no generalizations can be made. Present methods of decorating favor foil and paper surfaces over unsupported film, which requires oxidative treatment to be receptive to ink. Also, printing is made more difficult on unsupported film for the same stress-strain reasons which limits its use on automatic packaging equipment. On the other hand polyethylene film is transparent, and apparently there are a number of people who feel that uncooked foods are favorable visual stimuli. This is a very moot point, however, and is an ideal example of the subjective nature of "appearance."

SUMMARY

This comparison of unsupported polyethylene film with polyethylene-paper and foil laminates in the three major requirements of automatic packaging materials show the following:

Protection

Unsupported film yields greater water vapor and mechanical protection per dollar spent than poly-kraft and waxed cereal glassine laminations. Poly-wax combination lami-

nates, on the other hand, are quite superior to unsupported film, and where end-use conditions are favorable, they represent the most economical protection. Where such low water vapor penetration, bordering on absolute protection, is required foil laminates are a must, even though they are high-priced. Such foil combinations are, however, less costly than extremely heavy poly films.

Machinability

Because of the high-stretch, low-tensile properties of unsupported poly film, it cannot be run as efficiently as paper laminates on most automatic packaging equipment. Field experience has determined a limited area in the stress-strain relationship where suitable fast operation is possible, and paper or foil is necessary to meet this requirement. Ease of heat sealing also favors paper laminates.

Appearance

Appearance of the finished package is quite subjective. However, present techniques of printing favor paper or foil surfaces over polyethylene. Also, the rigidity of paper laminates is frequently desirable in the finished package.

CONCLUSIONS

These conclusions suggest that poly-wax paper combinations could have a superior role in food packaging because they have greater protective properties than unsupported poly film, waxed cereal glassine, and poly-kraft laminations, and still remain in competitive cost range. They meet the requirements of machinability as well as the poly-kraft laminations.

This work further suggests that unsupported film could be utilized more fully if a method of stabilizing the stretch in the machine direction could be achieved in order to produce a stress-strain relationship which would meet the requirements of automatic packaging machines.

Received Dec. 2, 1959. Presented at the 14th Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, held in Chicago, Ill., Sept. 21–23, 1959.

APPENDIX

SAMPLE IDENTIFICATION

1 Type I polyethylene—0.001 in.
2 Type I polyethylene—0.002 in.
3 Type I polyethylene—0.004 in.
4 Type I polyethylene—0.006 in.
5 Type I polyethylene—0.010 in.
6 Type III polyethylene—0.001 in.
7 Type III polyethylene—0.0015 in.
8 25 lb. MG Bl. kraft/5-lb. Type 1 polyethylene
9 25 lb. MG Bl. kraft/10-lb. Type 1 polyethylene
10 25 lb. MG Bl. kraft/15-lb. Type 1 polyethylene
11 25 lb. MG Bl. kraft/20-lb. Type 1 polyethylene
12 25 lb. MG Bl. kraft/30-lb. Type 1 polyethylene
13 25 lb. MG Bl. kraft/45-lb. Type 1 polyethylene
14 25 lb. MG Bl. kraft/10-lb. Type III polyethylene
15 25 lb. MG Bl. kraft/15-lb. Type III polyethylene
16 25-lb. Bl. kraft/6-lb. poly/0.0003-in. foil/15-lb. poly.
17 25-lb. Bl. kraft/6-lb. poly/0.00035-in. foil/15 lb. poly.
18 25-lb. Bl. kraft/6-lb. poly/0.0005-in. foil/15 lb. poly.
19 25-lb. Bl. kraft/6-lb. poly/0.001-in. foil/15-lb. poly.
20 1.5-lb. wax/25-lb. Bl. cereal glassine/1.5-lb. wax
21 3.5-lb. wax/25-lb. Bl. cereal glassine/3.5-lb. wax
22 6.0-lb. wax/25-lb. Bl. cereal glassine/6.0-lb. wax
23 3.5-lb. wax/18-lb. S.C. kraft/5-lb. poly/3.5 wax
24 3.5-lb. wax/18-lb. S.C. kraft/10-lb. poly/3.5 wax
25 18-lb. S.C. kraft/5-lb. poly/8-lb. poly/5-lb. poly/18-lb. S.C. kraft

An Evaluation of the "80-Grit Touch-Up" Method for Maintaining Calibration of the Valley Laboratory Beater

FRANK DINGER

The conditioning and calibrating of the laboratory beater has always been a rather complicated, time consuming problem. This problem has been simplified by the use of the "80-grit touch-up" method at the Puget Sound Pulp & Timber Co's laboratory. The "80-grit touch-up" method has given dependable reproducible results for more than 5 years.

DEVELOPMENT OF THE METHOD

The need for a dependable reproducible method for maintaining and calibrating the laboratory beaters became evident early in 1952. At this time an extensive testing program was being planned and the problem was attacked in the following manner. First, a well-aged, standard reference pulp was selected for the study. Second, one beater was carefully calibrated by TAPPI Standard T 200. The strength development characteristics for the reference pulp were established from tests run in the standard beater. Third, all testing equipment which was used in conjunction with the beater was checked and adjusted. Fourth, another beater was selected to study the effect of a number of variables. The following factors or conditions were varied on the beater for the study.

1. The surface of the beating tackle was varied from an 80-grit grind to a polished surface.
2. The radius of relief on the fly bars leading edge was varied from no relief to approximately $^1/_{16}$ in.
3. The width of the exposed lead on the bed plate approach was varied from $^1/_4$ to $^1/_{16}$ in.
4. The contact pressure between the bed plate and roll was varied through a range of 2.5 to 6.5 kg. on the bed plate arm.

Beater test results were obtained, for each condition of the factors varied, for comparison with the established values for the reference pulp.

PROCEDURE AND RESULTS

The two factors, surface roughness and radius of relief were studied together. The results of this study indicated a maximum strength development at 250 cc. C.S.F. was dependent upon the proper radius of relief on the fly bars leading edge rather than on the surface condition of the beating tackle, Dinger.* The results of the study, when repeated, were confirmed showing that each surface condition was capable of maximum strength development if the leading edge of the fly bars was sufficiently relieved. In addition, the test results indicated that no increase in strength development occurred for the 80-grit surface by additional relief on the fly bars. With the beater in this condition, the beating time to 250 cc. C.S.F. was quite fast (e.g., 27 to 32 min.). Since the desired beating time to 250 cc. C.S.F. was over 40 min., a method for obtaining this had to be found. This could be accomplished by additional relief on the fly bars leading edge, by running a number of charges of bleached sulfite pulp in the beater, or by reducing the contact pressure on the beating tackle. The method of running several (4 to 6) charges of bleached pulp in the beater was found to be quite desirable and was adopted. When the contact pressure on the beating tackle was varied from 2.5 to 6.5 k. on the bed plate arm the maximum strength development remained constant but a significant change in beating time to the 250 cc. C.S.F. level occurred. Since 5.5 kg. was the standard weight on the bed plate arm, this was also adopted for the "80-grit touch-up" method.

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Table I. A Typical Repair Schedule Required with the "80-Grit Touch-Up" Method, No. 1 Beater

June, 1952	Replaced fly bars, bed plate, bearings and diaphragm for study of beater calibration.
November, 1952	Beater put into regular production service with the "80-grit touch-up" method.
September, 1953	Replaced diaphragm.
August, 1955	Replaced fly bars, bed plate, and diaphragm.
October, 1956	Beater out of calibration—tub bottom built-up at roll approach with no improvement. Bearings to be replaced when one bearing support was found broken. This repair put beater into calibration again.
May, 1957	Replaced diaphragm when object removed from bed-plate well.
October, 1957	Made adjustment to side clearance on roll.
February, 1958	Replaced diaphragm.
July, 1959	Replaced diaphragm.

Only a limited amount of work was done on the effect of the width of exposed lead at the bed plate approach. No significant change in the maximum strength level at 250 cc. C.S.F. for the reference pulp was observed for an exposed lead width of $^1/_{16}$ or $^1/_4$ in.

The approach between the bottom of the beater tub and the bed plate should provide a smooth flow for the stock to minimize the turbulence at this point. A recent experience with no. 1 beater rather conclusively disproved this point. A discussion of the experience will appear at a latter point in the paper.

From the study at this point, the 80-grit ground in beating surface was found to be capable of a maximum strength development at 250 cc. C.S.F. In addition, a reasonable beating time to 250 cc. C.S.F. was easily obtained. But two questions had to be answered; one, could the beating time to 250 cc. C.S.F. for the reference pulp be maintained within reasonable limits? And two, would the beater continue to give reproducible results for the reference pulp? A periodic "80-grit touch-up" was found to be an effective method for maintaining a reasonable control of the beating time to 250 cc. C.S.F. for the reference pulp. Also, the test results showed that the beater would continue to give reproducible results.

Basically, the "80-grit touch-up" method is quite simple and requires a minimum of attention, thus allotting more time to other problems. The procedure for conditioning and maintaining the beater is as follows: The beater is ground-in using a partly beaten pulp slurry containing 100 g. of 80-grit silicon carbide carborundum. The grinding contact is controlled with an adjustable clamp on the bed plate arm. The grinding-in is complete when all of the bed plate surface makes contact with the roll fly bars. The beater's beating time is then adjusted by running 4 to 6 charges of bleached sulfite pulp in the beater. This is followed by a calibration test on the reference pulp to determine if the strength development characteristics are in calibration. The beater is now ready for production testing.

Each furnish of pulp beaten in the beater has a slowing down effect on the beater. When the beating time to 250 cc. C.S.F. for the reference pulp is over 45 min., the beater requires a touch-up. The procedure for the "80-grit touch-up" is as follows: Fifteen grams of 80-grit carborundum are added to the pulp remaining in the beater at the completion of a beater test. The addition is made with the bar raised and then 1-sec. intervals of contact are used for touching up the beating surfaces. Experience has shown that each second of contact will reduce the beating time to 250 cc. C.S.F. by 2 to 4 min. With a little experience, the beating time can be controlled quite closely.

A recent experience with no. 1 beater found it to be out of calibration, yet all previous tests indicated the beater was in good calibration. It was then learned that the drain plug had accidentally become lodged between the bed plate and the fly bars. An inspection of the bars in the roll and the bed plate revealed no damage. Yet, the beater continued to be out of calibration following a grinding-in. The design of this particular beater would not permit a smooth flow of stock between the tub bottom and the bed-plate approach. The bed plate extended approximately $^1/_4$ in. above the tub bottom. To improve this condition, the tub bottom was built up to conform with the bed-plate level. The beater continued to give out-of-calibration results and further inspections were planned. A check of the roll found it was not out-of-round and the bearings were not damaged, but one support of the bearing mount was broken. The break was repaired and the beater returned to proper calibration. This experience indicated that the flow conditions ahead of the bed plate was not an important factor but a slight misalignment of the roll had a significant effect on the beating action.

A typical schedule of beater repairs required by a beater using the "80-grit touch-up" method for maintaining calibration is presented in Table I. Replacement of the rubber diaphragm is shown as the most common cause for repair. Also, 1 to 2 years of repair-free use is quite common for a beater. A set of fly bars and a bed plate will give 4 to 5 years of dependable reproducible results with the "80-grit touch-

Table IIa. A Tabulation of the 250 cc. C.S.F. Test Values for a Calibration Pulp. The Results Shown Are for Tests Before and After a Special Test on a Grade or Kind of Pulp Other Than a Regular Bleached Sulfite Pulp

For Calibration Pulp C-9

Pulp grade or kind tested	*Test sequence*	*Beating time, min.*	*250 cc. C.S.F. values*			
			Burst	*Tear*	*Fold*	*Density*
Unbleached sulfite softwood	Before	41	118	105	2300	0.833
	After	42	118	109	1800	0.842
Rayon grade sulfite softwood	Before	44	117	105	2200	0.852
	After	41	118	105	2300	0.833
Semibleached sulfite softwood	Before	39	118	106	2500	0.846
	After	44	117	105	2200	0.852
Bleached kraft softwood	Before	37	118	104	1800	0.846
	After	37	118	113	2300	0.849
Bleached kraft hardwood	Before	38	118	106	2200	0.852
	After	37	117	110	2200	0.846
Bleached sulfite pine	Before	39	116	99	1700	0.851
	After	42	116	101	1900	0.834
Rayon grade sulfite softwood	Before	41	115	110	2300	0.831
	After	39	118	112	2100	0.845
Bleached sulfite rayon acetate grade	Before	40	118	113	2500	0.852
	After	44	117	105	2200	0.852
Bleached sulfite hardwood	Before	46	119	117	2400	0.835
	After	43	117	110	2200	0.838
Bleached kraft hardwood	Before	42	118	114	2500	0.848
	After	47	118	117	2500	0.830
Average values for Pulp C-9		41	117	107	2100	0.842

Table IIb. A Tabulation of the 250 cc. C.S.F. Test Values for a Calibration Pulp. The Results Shown Are for Tests Before and After a Special Test on a Grade or Kind of Pulp Other Than a Regular Bleached Sulfite Pulp

For Calibration Pulp C-7

Pulp grade or kind tested	*Test sequence*	*Beating time, min.*	*250 cc. C.S.F. values*			
			Burst	*Tear*	*Fold*	*Density*
Bleached kraft softwood	Before	38	111	112	1700	0.841
	After	37	113	96	1600	0.831
Bleached kraft softwood	Before	38	113	96	1600	0.831
	After	40	113	105	1800	0.852
Bleached kraft hardwood	Before	38	112	110	1700	0.842
	After	37	113	96	1600	0.836
Bleached kraft hardwood	Before	43	113	94	1600	0.844
	After	43	111	102	1800	0.836
Bleached sulfite hardwood	Before	38	113	96	1600	0.832
	After	40	113	105	1900	0.850
Bleached sulfite hardwood	Before	38	111	110	1700	0.842
	After	38	113	98	1600	0.833
Bleached sulfite rayon grade	Before	37	112	101	1600	0.834
	After	43	114	104	1850	0.820
Bleached sulfite glassine grade	Before	48	116	106	1500	0.841
	After	42	114	101	2100	0.844
Bleached soda hardwood	Before	39	112	97	2100	0.841
	After	40	113	105	1900	0.852
Bleached kraft hardwood	Before	38	111	110	1700	0.841
	After	38	113	97	1600	0.833
Average values for pulp C-7		42	112	104	1850	0.845

up" method. Experience has shown that the principle wear is from grinding-in and not from the touch-ups. The testing records show that between 500 and 700 tests are processed in each beater per year. With this kind of a testing schedule, the need for a minimum beater repair as shown in Table I is very important.

One question is often asked: Can a beater which is conditioned and calibrated for a sulfite pulp be used for testing other grades and kinds of pulp, e.g., bleached kraft? Test results indicate that the "80-grit touch-up" method has lent itself quite well to testing all grades and kinds of pulp with no serious effect on the beater calibration. Evidence of the beater being used for testing other grades and kinds of pulp is presented in Table IIa and IIb. The results tabulated are the 250 cc. C.S.F. values for two reference pulps C-9 and C-7 in Tables IIa and IIb. For each of the special pulp grades listed, the *before* and *after* test on the reference pulp is presented. In our evaluation of the calibration data, the mullen value at 250 cc. C.S.F. is used to express proper calibration. The burst values in these two series show a maximum variation of +3 points and −2 points from the established average values. Yet, most of the tests show a variation of only ±1 point of burst from the average. This is less than 2% variation.

Another series of test results is presented in Table III for an "80-grit touch-up" conditioned beater. The two reference pulps selected for this series were a bleached sulfite pulp and a bleached kraft pulp of softwood. The series of tests was completed in one beater by three testers. The tests in the series were alternated between the two reference pulps, as listed. The results indicate that a bleached sulfite reference pulp strength development and a beater calibrated by the "80-grit touch-up" method are not affected by testing kraft pulp in the beater. The results for the kraft pulp indicate that a beater calibrated by the "80-grit touch-up" method also gives dependable reproducible results with a kraft pulp.

A number of different grades and kinds of pulp have been tested in the beaters during the past 5 years. Several of these pulps were selected for retesting currently. A comparison of the original test and the retested values for beating time, burst, tear, fold, and density at 250 cc. C.S.F. is presented in Tables IVa, IVb, IVc, IVd and IVe. The time laps between the original test and the retested values range from 5 years to a few months.

The data presented in Table IVa is for a group of bleached sulfite pulps of softwood. The variation of the burst value between the original and the retest are excellent except in three cases. The loss in strength, shown by the three pulps C, D and I is probably due to an aging effect during storage. The I sample was a wet glassine pulp and the loss in strength was due to the air-drying effect on the pulp in storage. Each of the other tests presented tear, fold, and density also displayed a good reproducibility.

The data presented in Table IVb is for a group of bleached kraft pulps of softwood. The reproducibility for all of the pulps in this group was good for each of the tests: burst, tear, fold, and density. The group includes a wide variety of bleached kraft pulps from many different areas.

The data presented in Tables IVc and IVd are for a group of bleached kraft pulps and bleached sulfite pulps made of

Table III. A Tabulation of the 250 cc. C.S.F. Test Values Obtained on a Bleached Kraft and Bleached Sulfite Calibration Pulp from a Series of Consecutive Tests Run in a Single Beater

Test no. in series	*Calibration pulp no.*	*Beating time, min.*	*250 cc. C.S.F. values*				
			Burst	*Tear*	*Fold*	*Density*	*Tester*
1	C-9[a]	44	118	111	1900	0.836	A
2	K-1[b]	49	141	170	2100	0.734	A
3	C-9	42	119	109	1800	0.842	A
4	K-1	40	138	166	2150	0.735	B
5	C-9	45	118	108	1900	0.832	B
6	K-1	47	139	170	2200	0.752	A
7	C-9	38	116	111	1900	0.826	A
8	K-1	49	138	174	2100	0.722	B
9	C-9	47	119	108	1850	0.840	B
10	K-1	53	140	174	2400	0.720	C
11	C-9	46	119	117	2100	0.820	C

[a] C-9 = Bleached sulfite reference pulp.
[b] K-1 = Bleached kraft reference pulp.

Table IVa. Reproducibility of 250 cc. C.S.F. Test Values on Numerous Grades and Kinds of Pulp Samples Which Were Tested and Retested on Different Dates

Bleached Sulfite, Softwood

Code	Beating time, min.	250 cc. C.S.F. values: Burst	Tear	Fold	Density	Date tested
A	39	100	105	1100	0.824	5–58
A	35	100	106	1200	0.812	4–59
B	36	134	79	3100	0.923	9–58
B	32	133	80	2800	0.926	2–59
C	39	112	86	1700	0.910	3–54
C	38	108	84	1200	0.878	6–59
D	42	111	98	1850	0.839	5–57
D	44	107	93	1700	0.839	4–59
E	37	78	118	360	0.781	4–58
E	44	77	120	400	0.794	5–59
F	40	92	139	800	0.792	4–58
F	46	92	132	1000	0.806	5–59
G	39	107	99	1700	0.822	5–58
G	46	108	110	1750	0.827	7–59
H	36	103	96	1000	0.837	4–58
H	38	102	90	1100	0.840	6–59
I	49	126	88	1900	0.907	6–58
I	45	115	91	2000	0.905	6–59
J	42	90	88	900	0.866	5–57
J	44	93	89	500	0.851	6–59

hardwood. The reproducibility between the original tests and the retested values for these groups of hardwood pulps are all good. A beater conditioned and maintained by the "80-grit touch-up" method has been shown to provide a useful tool for the evaluation of these special hardwood pulps.

The data presented in Table IVe is for a group of special bleached, neutral sulfite, semichemical hardwood pulps. The reproducibility of the mullen at 250 cc. C.S.F. for this group was quite poor, which may be a characteristic of the particular pulp samples. The other tests tear, fold, and density were reproduced quite well.

The over-all reproducibility of all of the special grades and kinds of pulps presented in the Table IV series was quite good. One point should be made which could have an important bearing. The original test and the retest were often run in different beaters and tested by different testers.

During the past 7 years six bleached sulfite, reference pulps were used for checking the calibration of the beaters which were conditioned and maintained with the "80-grit touch-up" method. The standard deviation was calculated from the test results for each pulp for burst, tear and fold values. The burst and fold values include the 550 to 400 and 250 cc. C.S.F. values and the tear values at 250 cc. C.S.F., only. A tabulation of the standard deviations for the six pulps is presented in Table V. The calculations were made using all of the test results for each pulp which included some out-of-calibration tests. Examination of the standard deviations for burst at 250 cc. C.S.F. for the six pulps shows a range of ±1.77

Table IVb. Reproducibility of 250 cc. C.S.F. Test Values on Numerous Grades and Kinds of Pulp Samples Which Were Tested and Retested on Different Dates

Bleached Kraft, Softwood

Code	Beating time, min.	250 cc. C.S.F. values: Burst	Tear	Fold	Density	Date tested
AK	35	108	116	1050	0.740	4/57
AK	34	107	105	800	0.750	5/59
BK	47	138	170	2250	0.752	6/59
BK	45	135	170	2100	0.735	7/59
CK	50	159	158	3000	0.766	4/57
CK	56	161	163	3200	0.766	6/59
DK	47	163	108	3400	0.841	7/57
DK	46	160	104	4200	0.828	6/59
EK	37	143	126	2500	0.798	12/53
EK	40	141	123	2500	0.773	7/59
FK	44	126	132	1600	0.744	3/57
FK	40	129	128	1700	0.720	7/59
GK	48	132	159	2100	0.723	3/57
GK	46	133	152	2600	0.717	7/59
HK	38	134	147	2000	0.752	4/58
HK	49	136	148	2100	0.736	7/59

Table IVc. Reproducibility of 250 cc. C.S.F. Test Values on Numerous Grades and Kinds of Pulp Samples Which Were Tested and Retested on Different Dates

Bleached Kraft, Hardwood

Code	Beating time, min.	250 cc. C.S.F. values: Burst	Tear	Fold	Density	Date tested
AH	36	88	114	600	0.747	3/57
AH	33	90	118	550	0.726	7/59
BH	36	88	113	300	0.761	4/58
BH	37	86	114	500	0.771	7/59
CH	44	96	106	550	0.786	4/58
CH	53	99	108	800	0.785	7/59
DH	34	120	89	1200	0.864	10/58
DH	34	122	93	1150	0.860	7/59

Table IVd. Reproducibility of 250 cc. C.S.F. Test Values on Numerous Grades and Kinds of Pulp Samples Which Were Tested and Retested on Different Dates

Bleached Sulfite, Hardwood

Code	Beating time, min.	250 cc. C.S.F. values				Date tested
		Burst	Tear	Fold	Density	
ASH	37	72	91	230	0.844	5/58
ASH	43	67	84	200	0.849	6/59
BSH	41	72	90	150	0.834	4/58
BSH	46	70	90	200	0.853	6/59
CSH	48	37	56	...	0.816	4/58
CSH	41	33	57	...	0.791	7/59

to ±2.25 points with an average of ±2.00 points of burst. If the average was applied to a control chart in which the upper and lower control limits were approximately 3 times the standard deviation the limits of the chart would be ±6 points of burst from the mean value. For example, a reference pulp having a mean value for the burst of 115 would extend from 109 to 121 points of burst. Experience has shown that the test values of a reference pulp seldom show that wide a range of values. Normally, the burst test values at 250 cc. C.S.F. will generally fall within twice the standard deviation, or ±4 points of burst. Several variables are included in the test data in addition to the "80-grit touch-up" method. (1) The test data includes data from three beaters; (2) the test data includes tests run by six or more pulp testers; (3) each of the reference pulps, although well aged, continues to show a gradual loss in burst due to aging.

The standard deviation for the tear at 250 cc. C.S.F. was much higher than for the burst. The standard deviation of the tear ranged from ±3.2 to ±8.1 with an average just under ±5.0. The test data shows the tear value will vary ±10 points from the mean tear. The greater variation shown by the tear test is probably due to the nature of the test itself. Often one of the three tear values obtained from a tear specimen will be quite different from the other two values.

The standard deviation for the fold value at 250 cc. C.S.F. ranged from ±190 to ±248 double folds. Again, the test results show that for a single reference pulp the 250 cc. C.S.F. fold values will normally vary about ±400 double folds from the mean fold value. From the data presented in Table V, it is apparent that the "80-grit touch-up" method has continued to give dependable and reproducible results for more than 5 years after its first report, Dinger.

Table IVe. Reproducibility of 250 cc. C.S.F. Test Values on Numerous Grades and Kinds of Pulp Samples Which Were Tested and Retested on Different Dates

Bleached Neutral Sulfite Semichemical, Hardwood

Code	Min.	250 cc. C.S.F. values				Date tested
		Burst	Tear	Fold	Density	
ASC	15	102	124	600	0.734	4/56
ASC	19	100	128	600	0.733	7/59
BSC	20	88	134	325	0.705	6/57
BSC	18	95	132	500	0.710	7/59
CSC	18	83	96	275	0.802	6/57
CSC	25	75	100	200	0.778	7/59

Table V. A Tabulation of the Standard Deviation of the Test Results for Six Reference Pulps Used for Beater Calibration with the 80-Grit Touch-Up Method. The Results Include Test in Three Beaters and by Six Testers

Pulp no.	No. tests	Test	Standard deviation at freeness 550 cc.	400 cc.	250 cc.
C-1	39	Burst	3.10	1.51	2.03
		Tear	...	...	3.24
		Fold	114	150	190
C-2	40	Burst	3.27	2.34	2.08
		Tear	...	...	3.42
		Fold	126	183	229
C-3	114	Burst	2.74	1.97	1.92
		Tear	...	...	4.96
		Fold	120	151	220
C-4	101	Burst	3.62	2.69	1.97
		Tear	...	...	5.66
		Fold	122	136	213
C-7	101	Burst	3.27	2.76	2.25
		Tear	...	...	4.20
		Fold	129	178	230
C-9	25	Burst	3.64	2.04	1.77
		Tear	...	...	8.08
		Fold	130	173	248

CONCLUSION

I would like to sum up the evaluation of the "80-grit touch-up" method for maintaining the laboratory beater in calibration as follows:

1. The beater requires a minimum of repair and maintenance, often serving 1 to 2 years between repairs.
2. A set of fly bars and bed plate will give dependable service for more than 4 to 5 years.
3. The principal wear on the beating tackle is from grinding in the beater. Only, a minimum of wear results from the touch-ups.
4. Proper alignment between the bottom of the beater tub and the bed plate approach is desirable, but experience indicated the factor was relatively unimportant.
5. Testing of grades and kinds of pulp other than regular, bleached sulfite pulp have no noticeable affect on the calibration of the beater.
6. Dependable reproducible results are obtained with a bleached sulfite reference pulp or a bleached kraft reference pulp of softwood.
7. Reproducible results are obtained for many grades and kinds of pulp including both the softwood and hardwood pulps.
8. The "80-grit touch-up" method has given more than 5 years of dependably reproducible results following the first 18 months of use.
9. An average standard deviation for six reference pulps used over a 7-year period was ±2.0 points of mullen, ±5.0

points of tear and ±200 double folds at the 250 cc. C.S.F. values.

10. A failure to achieve normal calibration has been traced in the majority of cases, to improper tester technique or to the other testing equipment used along with a complete beater test.

Received Sept. 9, 1959. Presented at the 10th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Portland, Ore., Aug. 17–21, 1959.

The BRDA Scoreability Tester

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For years folding boxboard makers used the "hand bend" test to predict satisfactory scoreability. Board judged "good bender" by this test frequently resulted in cracked scorelines when processed into cartons. The need obviously existed for a rapid reproducible standard test method that would furnish a realistic numerical evaluation for the bending quality of folding boxboard as it was being manufactured.

The paper reviews the program undertaken by the Boxboard Research and Development Association to develop an instrument and test procedure to evaluate board scoreability. The BRDA scoreability tester, after 5 yr. of research and field testing, is presented as an instrument that provides a reproducible numerical rating of the scoreability of folding boxboard.

Five years ago members of the Boxboard Research and Development Association agreed that variation in the scoreability of folding boxboard was a common cause of waste in folding carton production. The only widely used evaluation of bending quality was the corner bend test. In this test, a sample of paperboard is hand folded from top to back through 180° at an angle of 45° to the machine and cross directions. An observation is made for cracking of the top liner. The test is subject to many variations, and does not provide any gradation of bending quality except good and bad.

The need for a better scoreability test arose from carton shop experience with variable bending quality within lots of paperboard. Typically, the folding carton fabricator would apply a creasing makeready for a given lot of board. However, cracked scores were evident within the lot without any change in creasing conditions. After much makeready manipulation, appreciable loss of production time, and considerable loss of patience, the creasing foreman would be forced to release cartons for gluing with partly cracked scores, ragged folding scores and poor panel alignment. The carton converter would complain to the mill about poor bending quality, and in many cases either returned board for credit (if he could) or turned out excessively expensive cartons due to not having to absorb the cost of unusable board but also wasted throwout cartons due to score cracking.

The quality mill, in an effort to give his converter better bending quality, would often strengthen the furnish in the board. Often this move was costly for he had to go overboard in an attempt to guarantee bending quality, since he had no good yardstick with which to judge bending quality. The board manufacturer would strengthen furnishes during fall and spring seasons, and this raised the possibility in his mind that perhaps humidification for the converter might save both mill and carton shop some excessive costs. In the final analysis, the mill had no way of knowing whether or not the carton maker had all the appropriate knowledge on how to convert board satisfactorily at any bending quality level.

R. L. Lewis, Technical Director, and C. G. Eckhart, Development Chemical Engineer, Ohio Boxboard, Rittman, Ohio. A. T. Luey, Executive Secretary, Boxboard Research and Development Association.

Since no reliable, well established method for bender evaluation existed among Association members, a research project was established at Battelle Memorial Institute "to develop a test method for evaluation folding boxboard for its ability to crease properly." The anticipated benefits of this project were less board rejections by the carton maker, less makeready time and greater production efficiency by the carton fabricator, and improved furnish costs for the board maker.

The primary objectives of the scoreability test development program were to develop a method which could assign a numerical value to the scoreability of boxboard, and to design and construct equipment by which this method could be used in boxboard mills and carton plants to control product quality.

DEVELOPMENT OF METHOD OF EVALUATION

Prior investigations into the numerical evaluation of paperboard scoreability utilized the principle of varying the creasing depth in order to differentiate between samples of good and poor bending quality (*1*, *2*). The initial study by Battelle indicated that *two* parameters were involved in the successful scoreability evaluation of paperboard. These two variables were reported (*3*) as the range of depth of male rule penetration and the range of female score widths (Fig. 1).

A scoring machine based on the principle of gradually increasing the depth of male rule penetration with varying width females was built by Battelle for exploratory evaluation. It was found that for samples, unrestrained at the ends, too wide a range of penetration depths and female score widths produced satisfactory scores and 180° folds. When the samples were restrained on the ends, so that the stretch due to male rule penetration was localized to a length corresponding to distances between commercial scorelines, a greatly reduced range of penetration depths and female score widths produced satisfactory scores and 180° folds.

It should be pointed out that the investigation of scoreability evaluation was directed at obtaining satisfactory scores perpendicular to the machine or grain direction of paperboard, since the greatest amount of difficulty is experienced with crossgrain or body scores.

A prototype scoring machine utilizing clamping bars for the ends of the samples was constructed for field evaluation. In

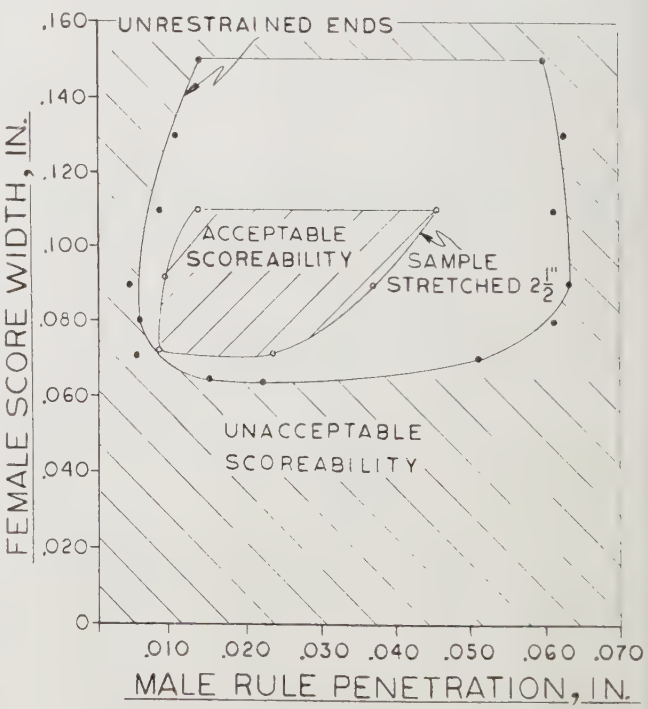

Fig. 1. Parameters of scoreability

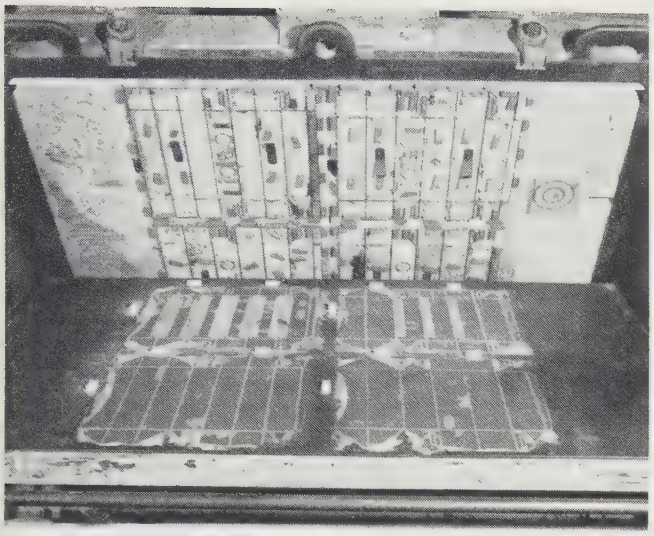

Fig. 2

this prototype, a slanting rule, designed to give a gradually increasing depth of penetration, was mounted over a constant width, female score. The depth of the female score was made 0.100 in. so that no back-up or bottoming occurred on the sample during scoring. The factor of female die depth was found to have little or no effect in the exploratory observations.

Although field tests on the prototype machine by Diamond-Gardner indicated that good and poor bending quality board could be evaluated satisfactorily, the instrument was relatively insensitive to intermediate grades of bending quality. Probably the chief reason that the instrument failed was the nonuniformity of most paperboard within relatively small areas of sample. Since the test was designed to yield an end point based on the minimum and maximum depths of penetration which produced satisfactory scores and 180° folds, the end point was subject to localized nonuniformity unless the sample size was made very large. In order to obtain a more reliable end-point evaluation not subject to board nonuniformity, this principle of evaluation was abandoned.

After re-investigation of the scoring variables, the range of female score widths was chosen as the parameter for further exploration. Suitable male and female die sets were made from all metal components and mounted in a platen semi-automatic press. Since male scoring rule varies in width with board caliper being scored, the male rule sizes were chosen for the caliper ranges of paperboard in accord with the average commerial box shop practice. For each male rule size a series of female score widths were laid out similar to those in use in the Ohio Boxboard bending test (*4*). This test had been developed in connection with actual production experience which indicated that score cracking could be minimized on a given job by increasing female score widths (Fig. 2). Determination of the increments in score width was based on the smallest average change which could be cut into tympan makeready by a pressman, and turned out to be 0.008 in. on a large number of measurements. In each of the die combinations used in the Ohio Boxboard test, the male rule penetration was held at a constant value. The depth of the female die was made 0.005 to 0.010 in. less than the caliper of the board since it was found that slight bottoming of the sample gave better score definition than lack of bottoming. Male rule penetration into the sample was made equal to or slightly greater than the caliper of the sample. This coincided with the midpoint of the original study on range of rule penetration depths.

The range of female score widths selected was based on the concept that the average score width for 180° folding without cracking should be twice the paperboard thickness plus the thickness of the scoring rule (*5*). Two scores wider than the average by 0.008-in. increments, and two scores narrower than the average by 0.008-in. increments were laid out with each male rule for a given paperboard caliper range (Fig. 3). Thus, a five-grade numerical evaluation was possible on each board caliper range if each score-width change represented a significant change in bending quality.

A complete description of the bending quality would involve knowing the minimum and maximum score widths which produce good folding at varying depths of rule penetration. However, for control testing we can use the parameter of minimum female score width with the depth of penetration held constant. Slight variations in depth of penetration do not appear significant and the type of scoring failures associated with maximum female scoring width are seldom of interest in commercial operations, because of score collapse or crush.

Experience with local variation in boxboard has indicated (and has been confirmed experimentally) that a single female score varying in width from narrow to wide would be unsatisfactory. Tests of an "end point" determination type appear to be basically unsatisfactory for paperboard (Fig. 4).

The male and female scoring components were permanently mounted in metal platens, and placed in a standard hydraulic press unit with positive stops (Fig. 5). The hydraulic unit selected delivered 1500 p.s.i.g. pressure, which was found to provide adequate pressure to duplicate commercial score appearance.

The unit did not deliver enough pressure to bottom the male die on heavy caliper, extra strength boards. This was overcome by reducing the sample width in the heavier grades. Thus, the available pressure was concentrated on a smaller area, and provided effective pressure to bottom the die.

The prototype scoreability tester incorporating female width as the parameter was field tested at the Ohio Boxboard

	Section 2	Section 3	Section 4
Caliper Range of Board, in.	.016 - .022	.022 - .030	.030 - .040
Rule, round-edge (thick.,in.)	2 point (.028)	3 point (.042)	4 point (.056)
Depth of Penetration, inch	Mean Board Caliper	Mean Board Caliper	Mean Board Caliper Plus 0.005
Depth of Female Die, inch	0.018	0.022	0.030
Width of Female Dies, inch	1 - 0.054 2 - 0.062 3 - 0.070 4 - 0.078 5 - 0.086 6 - 0.094	1 - 0.078 2 - 0.086 3 - 0.094 4 - 0.102 5 - 0.110 6 - 0.118	1 - 0.102 2 - 0.110 3 - 0.118 4 - 0.126 5 - 0.134 6 - 0.142

Fig. 3. Specifications for BRDA scoreability tester dies

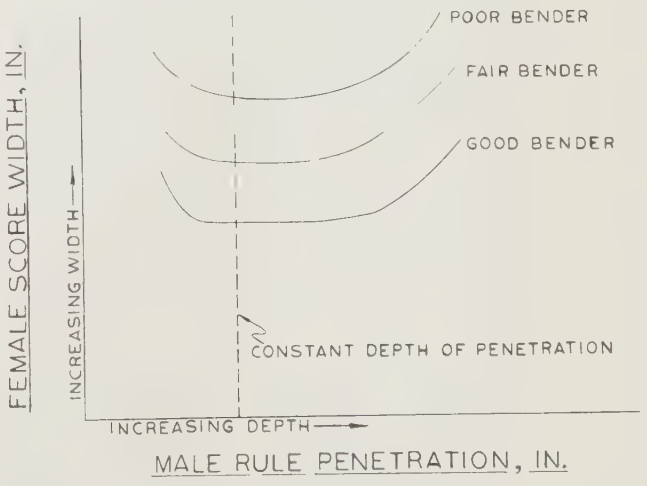

Fig. 4. Scoreability evaluation at constant male rule penetration

Fig. 5

Co. in order to evaluate the ability of the tester to distinguish between grades of bending quality. Results of over 200 tests indicated satisfactory correlation with actual converting plant performance. All tests were performed under standardized testing conditions which are referred to later and production evaluation of the board was carried out by subjective assessment of both scoring and folded result. The bending quality number corresponds to a subjective or production assessment of the type of folded result which may be expected on cross-grain scores folded 180° as follows:

Bender No. 1—Excellent bender; should never result in cracked scores.
Bender No. 2—Good bender; should rarely result in cracked scores.
Bender No. 3—Fair bender; will occasionally produce cracked scores.
Bender No. 4—Marginal bender; will produce large quantities of cracked scores, can be processed satisfactorily only with exceptional makeready care.
Bender No. 5—Unsatisfactory bender; will always produce cracked scores regardless of makeready condition.

Five additional prototype machines were built and field tested in the member plants of Diamond-Gardner, Container Corporation of America, Continental Can, Waldorf and Sutherland. Experience confirmed the fact that bending quality could be evaluated routinely at the end of the board machine, and further that carton plant scoring performance could be predicted satisfactorily.

In order to determine whether the testers were of uniform conformance to manufacturing specifications, round robin tests were carried out on standard samples of various grades and calipers of board. Samples were preconditioned, scored and folded in a standard manner, and evaluated by the individual participant. Good agreement was found between testers and, after suitable discussion by participating members, it was agreed that the tester was suitable for release to other member companies. Twenty-three additional testers were put into use within the last year.

EFFECT OF MOISTURE CONTENT

During the field evaluation of the prototype machines extensive data were collected to show the effect of board moisture content during scoring on the folded result (*6*). Data collected by Diamond-Gardner showed that the bending quality decreases rapidly as the moisture content decreases below 6%, and increases slowly as the moisture content increases over 6% (Fig. 6). Conditioning samples at 35% R.H. (about 5% moisture content) was deemed appropriate for standard test conditions since at this moisture content the range of test results for difierent bending quality boards is a maximum for the instrument range. Moisture content of the samples must be carefully controlled, however, if reproducible results are expected.

STANDARD TEST PROCEDURE

Any test method is only as good as its reproducibility by many users on a uniform sample. Preliminary interlaboratory comparisons of the bending tester without defining conditions had shown relatively poor reproducibility. It was agreed to define standard test conditions based on a knowledge of the known variables, and repeat the comparisons.

Since moisture content was shown to be a major factor in bending quality determination, all samples were preconditioned to 35% R.H. for at least 30 min. in order to reach equilibrium bending number. Tests made by Diamond-Gardner showed that although extremes in moisture content samples required 120 min. to equalize in 35% R.H. to the 5% moisture content, the bending number was unchanged after 30 min. conditioning.

It was found desirable to cover the white surface of patent and clay coated boxboards with a colored film in order to make visual assessment of the bending number more apparent. Drawdowns with a Maier bar were made on the samples with a rapid drying dark gravure ink, and it was found that this method of coating application made bender evaluation easy to judge.

After scoring the coated conditioned sample, the folding of the scores produced some variation depending on the speed and pressure of folding. This variable was reduced to a minimum by making use of a $^3/_4$-in. diameter steel rod 6 in. long, which was pressed uniformly along the length of the hand-folded scoreline of the sample in contact with a flat surface. This pressing action simulates the action of the breaker rolls of a glue machine, and makes the folded score evaluation practical as well as uniform.

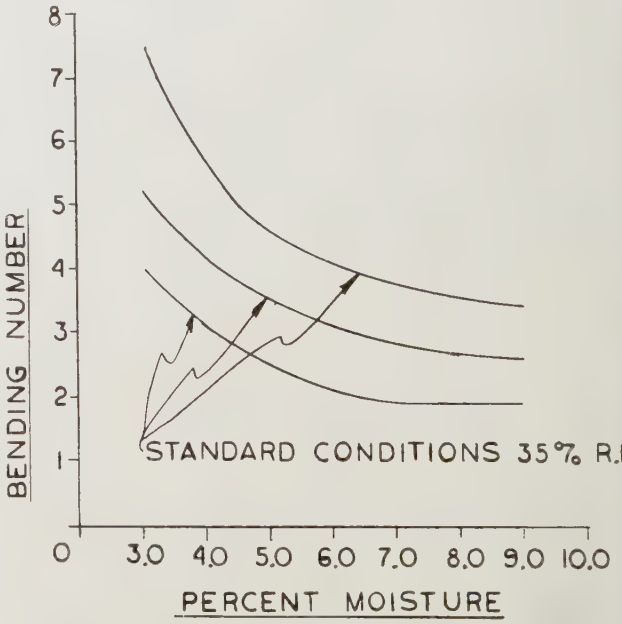

Fig. 6. Effect of moisture on bending quality

The standard test procedure to evaluate bending quality with the scoreability tester thus becomes (7):

1. Cut a representative sample of 4 × 12-in. grain long direction, for the caliper ranges applicable to 2 point and 3 point rule sections; 2 × 12-in. for caliper ranges to be tested with 4 point rule.

2. A thin film of dark gravure or flexographic ink is applied to the sample with a no. 12 or no. 14 Maier rod or other suitable applicator.

3. Precondition the sample at 35% R.H. for at least 30 min. A suitable cabinet for attaining this humidity should be located near the instrument. The cabinet must be accurately controlled at 35 + 0 to 5%. A home dehumidifier can be used to attain these conditions.

4. Place the sample in the proper section of the die as determined by the caliper of the board.

2-point rule section for 0.015 and including 0.021
3-point rule section for 0.022 and including 0.029
4-point rule section for 0.030 to 0.040

5. Score the sample. Fold each score 180° starting with the narrowest score, pressing the score down with moderate finger pressure and ironing with a $^3/_4$-in. polished steel roll. Examine the scores and determine the narrowest score which has no cracks.

6. Should the board sample bend satisfactorily on the narrowest score in the 3 or 4 point rule section, score a duplicate specimen in the next narrower section and complete the determination of the narrowest score which shows no cracking.

7. Report the average bending number as the rule number followed by the number of the narrowest score without a crack. For example, a 0.020 board cracks on the 2nd score in the 2-point rule section, but bends without cracking on the 3rd score. Its rating would be 2 to 3. Similarly, a 0.030 board which bends satisfactorily on the narrowest score at the 4-point rule section but cracks on the widest score of the 3-point rule section would be rated 4 to 1.

USE OF RESULTS

The primary use of scoreability evaluation is to control board bending quality at the end of the paperboard machine. The paperboard manufacturer needs to know the bending quality of his product before he has made many tons of unsalable material. Furnishes, moistures, and operating conditions may be changed immediately to bring the board bender to the desired level, and marginal or unsatisfactory bending board is separated promptly.

Results of bending quality evaluation may be used to set up specifications as to the level of bender required by customers on different types of board or end use requirements. For example, a customer may decide that he can use a lower level of bending quality on a carton not printed over the scorelines than on a carton printed and varnished over the scorelines. Another customer may be making long-grain type cartons with difficult definition with-grain scores, and require much better bender than a customer making the same size short-grain seal end cartons.

Experience to date with the tester indicates it is an aid to the carton plant in establishing proper scoring makeready. Knowledge of the board bender number has helped the pressman to select counter thickness, rule width and height and score width for a satisfactory makeready. This is especially applicable if there is a variation in bender within a given run, since it will allow him to adjust his makeready to process each kind of board satisfactorily.

The tester may also be used to determine the type of withgrain score which will produce satisfactory results. A set of lower height stops is furnished with the tester so that penetration depth of the male rules may be increased 0.005 in. This amount of increased penetration is normally used to form withgrain scores, and allows evaluation of the type of score which will need to be applied in commercial practice.

Experience has shown that a better bending quality board is normally required for satisfactory scoring and folding of carton board on cylinder creasers than platen creasers. This fact is undoubtedly related to the pressure per square inch of scoreline area which is greater at any given time on a cylinder creaser because of the area of contact. The increased shear due to the rolling crease apparently requires a stronger, more elastic top liner than the single impact platen action.

CONCLUSION

The BRDA scoreability tester is presented as a test instrument which has helped eliminate guesswork and misconceptions about bending quality evaluation throughout the folding carton industry. An evaluation of board bending quality is important from an economic standpoint to both producer and converter. The BRDA tester may be used as a qualtiy control tool to solve bending problems in both carton shop and mill.

The tester is being used by numerous mills and carton shops, and should be considered for acceptance as a standard bending quality test method by the folding boxboard industry.

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Received Sept. 17, 1959. Presented at the 10th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Portland, Ore., Aug. 17–21, 1959.

Radiant Burners for Conditioning Asphalt Coating on Sheathing

BORIS R. POLITICA

A new system for driving a uniform and permanent asphalt coating into sheathing, without leaving any black powder on the surface to rub off onto carpenters' hands, has been put into operation at the recently dedicated Johns-Manville plant in Klammath Falls, Ore. (Fig. 1).

The improved coating process, tailored for production of the company's Roofinsul® and Weathertite® boards (Fig. 2), is centered around the use of three pairs of steel calender rolls. Five of the rolls are heated *internally* with Duradiant burners patterned to give even-heat distribution across the face of the roll.

The graduation heating system in the ceramic cylinders, which were designed and built by Selas Corp. of America, Dresher, Pa., has eliminated the troublesome "hot-spot" problem encountered in coating and strike-in operations of this type. Sheathing board processed between the uniformly heated steel rolls comes off the production line without a trace of black residue left on the surface.

Located close to the inside surface of each steel roll to provide temperature uniformity, the Duradiant burners also fulfill the critical need for close temperature control. Predetermined temperatures of approximately 450°F. on the face of each steel roll are quickly reached and controlled within ±10°F., thereby eliminating the hazard of overheating, fuming, and asphalt flashing off the roll.

Boris R. Politica, Project Engineer, Johns-Manville Corp., Manville, N. J.

This heat control that is benefiting coating operations at the Johns-Manville plant results from the ability of the patterned burners to beam radiant heat directly to specified areas on the inner surface of the roll . . . exceptionally wide burner throttling ranges . . . and lower thermal inertia.

The burners are designed with scientifically grooved, cup-shaped refractory surfaces (Fig. 3). When controlled gas-air mixtures are burned against these ceramic surfaces, they become incandescent and beam radiant heat to the steel roll inner surface.

The high temperature gradient attained, coupled with close proximity of the burners to the steel roll inner surface, makes fast heat-ups possible. Such proximity is safe because the burners produce no harmful flame impingement, combustion being completed entirely within the cup. The wide throttling range of the burners and instantaneous response to temperature changes provide the flexibility needed to obtain and hold to the critical heat input requirements.

Measurements of heat are made from a thermocouple located close to the internal periphery of the rolls. A Wheelco Capacitrol detects temperature changes through this thermocouple and adjusts a Barber-Colman valve operator which varies fuel input to maintain a constant temperature.

Because this heating system responds readily to automatic control and is precise in its adherence to predetermined heating rates, a specific program that assures uniform coatings on both types and all sizes sheathing is being followed. The different sizes of boards being coated by the new method, all of which are made from wood pulp of Lodgepole Pine, include: (a) Roofinsul in thicknesses from $^1/_2$ to 3 in., in panel size of $24^7/_8$ by 48 in. (b) Weathertite in thicknesses from $^1/_2$ to $^{25}/_{32}$ in., in panels 2 by 8 ft., 4 by 8 ft., and 4 by 9 ft.

The coating operation, completely automatic except for the initial feeding of sheathing boards into the system by an operator, begins with the melting of asphalt. Once the asphalt charge has been brought to temperature, boards are removed from live pallets (see Fig. 1) and are loaded onto the feed conveyor one at a time by two operators. The boards, which are kept separated by approximately 1 in., then go through a brush-roll section to have all loose sawdust and foreign matter removed from surfaces prior to coating.

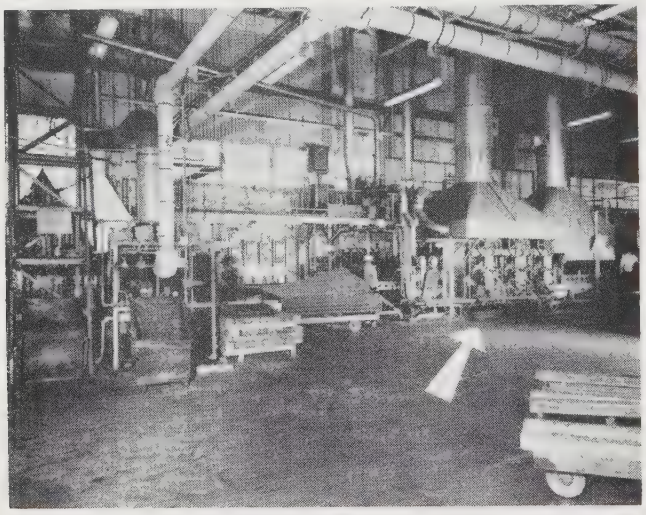

Fig. 1. Overall view of asphalt coating system, which was designed with the joint efforts of Johns-Manville Corp., Reichel & Drews, Inc., and Selas Corp. of America. Operators are removing Weather-tite® board from pallet to feed onto conveyor for automatic processing. Internally-fired steel rolls are located under the first exhaust canopy (note arrow)

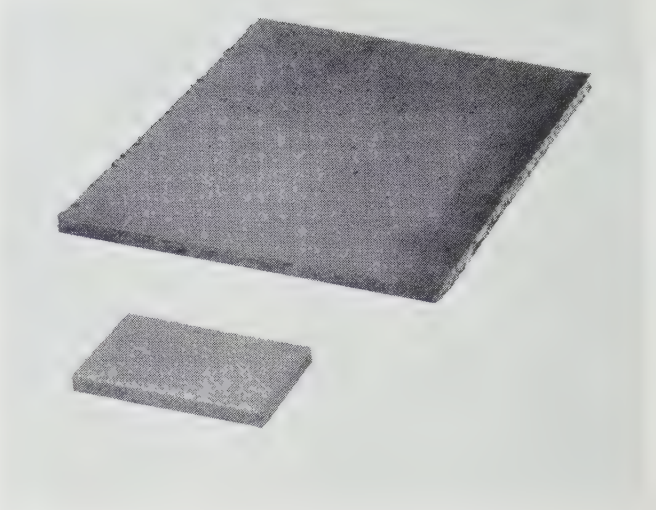

Fig. 2. Roofinsul® (bottom) and Weathertite® sheathing boards, after being asphalt-coated

Next, the boards travel through a hot asphalt puddle in front of the first pair of applicating rolls for surface and end coating. This is the first stage of the heating process itself, which is shown in Fig. 4. The "coating" is done over a backup plate, which is located on the entrance side of the applicating rolls and under the board being coated. The asphalt is puddled onto the top of the board, overflows the sides and coats the edges of the board.

As each board passes between the applicating rolls, the top roll, which is heated from within by Duradiant burners, acts as a "doctor roll" and forces excess asphalt over the edges of the board onto the coating pan. The bottom roll, unheated, picks up the asphalt from this pan and rolls it on the bottom of the board.

After this first step in the actual coating, the board passes between edge wipers, which spread the asphalt uniformly across the edges and wipe excess coating off into the coating pan.

The board is then ready for the critical part of the coating process, passing in between the second and third pairs of smooth-surfaced "strike-in" rolls (pictured in Fig. 5). Both the top and bottom roll of these two pairs are heated from

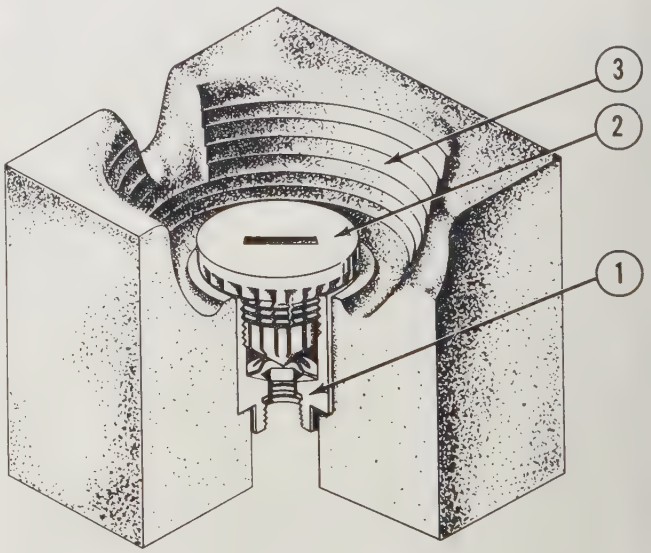

Fig. 3. Diagram of Duradiant burner operation. Gas-air mixture enters tube (1); moves to burner tip (2); passes through ports in tip and burns radially on the refractory cup surface (3)

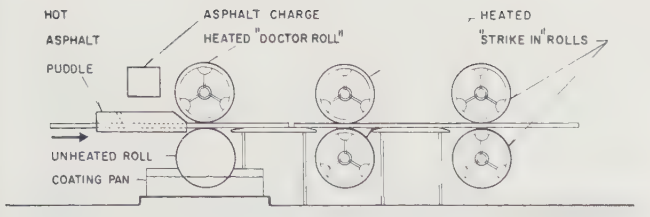

Fig. 4. Sheathing boards pass between three sets of steel rolls; five of the rolls heated internally. The heated "doctor roll," at top of first pair, forces excess asphalt from hot asphalt puddle over board edges into coating pan. Unheated roll at bottom picks up hot excess asphalt and applies it to bottom of board

within by the Duradiant burners to drive the asphalt into the board.

It is at this stage of the operation that the accuracy of temperature control and heating uniformity is imperative. The temperature must be brought precisely to the predetermined level *across the full face of the roll* so the asphalt will be driven into the board *uniformly* and meet specific permeability tests. Also, the temperature must be held below the fire point of the residue across the full length of the rolls to prevent asphalt flash-offs and fire hazards. Internal radiant heating of the rolls at Klammath Falls has eliminated flashbacks, improved the coating uniformity and quality of boards, and reduced rejects.

After passing between these second and third sets of rolls and being "ironed," the board travels through a fine mist spray, then is cooled and wiped free of moisture by high velocity, high volume "air knives."

The Roofinsul board, which is not monogrammed, is taken off the conveyor by a crew and stacked loose, hand-tied into bundles or hand wrapped. The Weathertite sheathing boards are conveyed out of the cooling section into a printer and "Johns-Manville Weathertite® Sheathing" is monogrammed on each board.

In addition to the elimination of surface residue and flash-offs, improved uniformity of coatings and fewer rejects, maintenance and repair savings are also mounting to a substantial figure. Internal roll heating, with combustion exhaust at the roll ends, creates a differential pressure within each roll. This causes outside air to move through the trunions and is preventing heat from soaking into the shaft and overheating bearings.

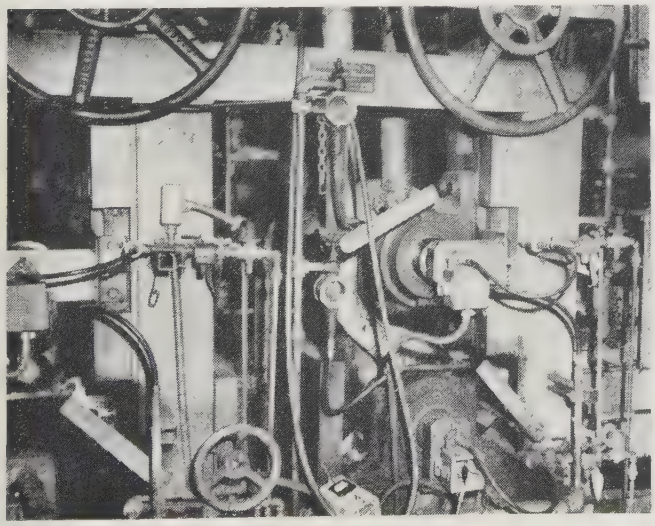

Fig. 5. Two pairs of "strike-in" rolls drive asphalt coating firmly into board, leaving no hand-blacking residue on surface

RECENT BOOKS

Plastics Engineering Handbook, 3rd Edition. New York, 1960. Reinhold Publishing Co. Cloth, 7 × 10, 565 pages. $15.

The official handbook of the Society of the Plastics Industry, Inc. The first edition appeared in 1947, the second in 1954. The subcommittees assigned to the task of compiling the third edition were composed, in part, of technicians who have kept abreast of the industry in their individual fields and, in part, of new members carefully chosen to provide a balance of practical experience and modern theory. Alan F. Randolph of E. I. du Pont de Nemours & Co. Inc. (retired) edited all of the copy.

The following chapter headings will indicate the nature of the subject-matter covered: classification of rigid molding materials, compression molding, cold molding, injection molding of thermoplastic materials, extrusion machines, reinforced plastics, cellular plastics, polystyrene, silicones, casting, vinyl dispersions, standards for tolerance, machining, cementing, plastics as adhesives, and commercial standards.

Handbook of Industrial Research Management. Edited by Carl Heyel. New York, 1959. Reinhold Publishing Co. Cloth, 6 × 9, 513 pages. $12.

Thirty-three experts in the field of industrial research management have pooled their experience in the preparation of this useful volume. In industry research is now recognized by management as being necessary for competitive survival, growth, and diversification. The book attempts to answer the questions. How can management, relative to research, fulfill its obligations of trusteeship over other people's money without stifling the creative spirit that thrives best when least controlled? How can research translate its visions, findings and promises into terms understandable by the decision makers? How can the front office best communicate policy objectives and economic limitations to the laboratory?

The main sections of the book deal with management perspectives of research organization basic research and patents; research perspectives of developing projects, executive direction and administration and use of electric computers; accounting, control and evaluation; personnel administration of recruiting, training, and compensation; and government contracts.

Marine Boring and Fouling Organisms. Edited by Dixy Lee Ray. Seattle, 1959. University of Washington Press. Cloth, 5½ × 9, 536 pages. $8.50.

This interesting book, published in photo-offset typewriter style, is the product of a symposium held by the Department of Zoology at the Friday Harbor Laboratories of the University of Washington. The symposium brought together a wide variety of professions and industrial representatives. The book is reviewed here because the problem of marine boring, etc., is closely related to the pulping of wood in its ramifications.

For the scientist, especially the biologist and biochemist, there are fundamental questions of fundamental importance to be examined. Do marine wood-borers actually feed upon the wood into which they burrow and which very likely passes through their digestive system? If so, how do they handle so unpromising a material as wood to extract from it the carbohydrates necessary for energy and for growth.

Considerable attention is given to limnoria, terediniens, and barnacles but 200 pages are devoted to a consideration of the cellulases, cellulose decomposition by fungi and bacteria of the sea, termite cellulase, cellulose digestion in insects and cellulolytic activity in teredo.

Acrylic Resins. By Milton B. Horn, Catalin Corp. of America. New York, 1960. Reinhold Publishing Co. Cloth, 5 × 7½, 185 pages. $4.50.

The fourteenth in a series of titles in the Reinhold Plastics Applications Series. The theme of the series is guidance in application. This volume describes the four types of acrylics in respect to their manufacture, fabrication, and applications. The acrylic monomers are a group of synthetic chemicals that form a suborder of the parent group of vinyl-type monomers. Among the subjects covered are the chemistry of acrylic monomers and polymers, molding powders, manufacture of acrylic emulsions and their application. A useful Appendix of selected reading material is included.

Recent Advances in the Chemistry of Cellulose and Starch. Edited by J. Honeyman. New York, 1959. Cloth, 6 × 9, 358 pages. $9.25.

This book consists of a series of 12 lectures given in 1958 under arrangement by the Manchester College of Science and Technology. Among the subjects covered are the chemistry of carbohydrates, the molecular and crystal structures of cellulose, the hydrolytic, oxidative and alkaline degradation of cellulose, mechanical properties of cellulose and cellulose derivatives, sorption of water by cellulose and starch, degree of polymerization of and the enzymic synthesis and degradation of cellulose and starch.

Naturharze Terpentinol Tallol Chemie und Technologie. By. W. Sandermann. Berlin, Germany, 1960. Springer-Verlag, West Berlin-Wilmersdorf (Heidelberger Platz 3). Cloth, 6 × 9, 484 pages. DM 62.40.

Dr. Sandermann is professor of organic chemistry at the University of Hamburg. In his preface he indicates that he knows about no other book or monograph on the subject of tall oil and oil of turpentine. His book attempts to fulfill this need. Starting with the history and statistics of the industry he covers the chemistry and biology of natural resin, the sources of resin and pine oil. More than 100 pages are devoted to the production, refining distillation and uses of tall oil, and the final chapter concerns itself with the analysis of rosin, tall oil, and oil of turpentine.

Handbook of Filtration. By the Technical Staff of the Eaton-Dikeman Co., Mt. Holly Springs, Pa., 1960. Cloth, 6 × 9, 112 pages. $2.50.

A survey of the latest developments of paper filtration. It is the stated purpose of the authors to present to the interested scientific audience a noncommercial manual summarizing data acquired in the past and presenting the most recent findings. Emphasis is given to the use of paper as the filter medium. The methods used for testing and evaluating filter paper are given. The illustrations of testing equipment enhance the understanding of these procedures which, for the most part are TAPPI Standards. Excellent chapters deal with the mechanisms of retention and the theoretical and practical aspects of permeability. In addition to a full consideration of filtration in the laboratory a comprehensive, well-illustrated chapter deals with industrial filtration. The various types of filter plates are illustrated. An appended glossary, literature citation, and index make the publication very useful as a reference handbook.

Amino Resins. By John F. Blais. Reinhold Publishing Corp., New York, 1959. 5 × 7¾, 220 pages. $4.95.

This is the thirteenth volume of the Reinhold Plastics Applications Series. It describes in semitechnical language the amino resin applications in adhesives, molding, laminating, textiles, paper, and surface coatings. Besides discussing the applications of the well-known urea and melamine resins the author also describes the chemistry and applications of the newer ethylene urea and guanamine resins.

Plant Pathology: An Advanced Treatise. Vol. 1: The Diseased Plant. Edited by J. G. Horsfall and A. E. Dimond. Academic Press, Inc., New York, 1959. 6¼ × 9¼, 674 pages. $22.00.

As implied by the title, this book covers the field of the sick plant. The beginnings of the science of plant pathology may well have started in the middle of the 19th century when De Bary (1866) and Berkeley (1857) made the breakthrough that clarified the role of the pathogen in disease; in fact the first viruses to be discovered were those that produce diseases in plants. Tobacco mosaic was the first to be purified and studied chemically.

To understand these afflictive processes, it is necessary to know how viruses get into the cells they infect, and once inside how they interfere with the internal composition of the cell. Recent work has shown that trees can also suffer from malnutrition. The symptoms of this condition, known as "tired sap," manifest themselves by certain mineral deficiencies.

The book is not for a beginner; it does not discuss the specific diseases of plants and their control. It deals with the concept of disease, obstruction of normal pathways in sick plants, how the pathogen impairs functioning of organs, and the reaction of host plants to the pathogen.

An international group of 19 plant pathologists have contributed to this volume.

Cellulose Pulp and Allied Products. By Julius Grant. Interscience Publishers, Inc., New York, 1959. Cloth, 5½ × 9, 512 pages. $8.50.

This book is essentially the third and revised edition of the author's book "Wood Pulp." However the author recognizes other sources of cellulose, especially for local consumption of pulps made from straws, bagasse, bamboo, esparto, grasses, etc.

The author covers the usual field of materials preparation, the mechanical and chemical processes, bleaching, mechanical purification, and dewatering. Special attention is given to hardwoods and semitropical conifers. It should be kept in mind that the book has been written with a background of European practices. Some terms are not used in American practice.

Paper Industry in India. 1959. By V. Podder. Published by Government of India, Minister of Industry, New Delhi, 1970. Paper cover, 6¼ × 9½, 100 pages.

An interesting and useful survey of the Indian paper industry prepared by V. Podder, works manager of Rohtas Industries, Ltd., Dalmanager, India. It was prepared for the benefit of delegates to a United Nations conference on paper to give them a birds-eye view of the Indian industry. Among the subjects covered are history, handmade paper, bamboo pulping, tariffs, production capacity, sabaigrass, bagasse, straw, mill machinery, statistics future demand, and various grades of paper and board.

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(P990-60)

Instrumentation Studies. LXXXVI. A Study of Photoelectric Instruments for the Measurement of Color: Reflectance and Transmittance

XIII. The Zeiss-Electrophotometer Elko II

LEONARD R. DEARTH, WAYNE M. SHILLCOX, and J. A. VAN DEN AKKER

The Zeiss-Electrophotometer Elko II is adaptable for use both as a reflection meter and a transmission-measuring instrument. It was examined and studied on the APPA instrumentation program as a reflection meter. The auxiliary reflectance attachment employs a 45–0° geometry attained through the use of a lens and prism arrangement. The specimen aperture (27 mm. diameter) is suitably located for evaluation of large specimens, but the area around the specimen aperture does not remain flat when the instrument is switched "on" and the temperature rises, thereby introducing a geometric variable that influences the ultimate reflectance value obtained. The instrument response is independent of variations in line voltage and frequency, even when the latter are large. A series of eight filters (including a filter specifically designed for brightness measurement) permits the measurement of reflectance at points across the visible spectrum, thus enabling one to control the color of "white" and lightly tinted papers. The instrument has good sensitivity. Standardization of the instrument is carried out by means of an opal glass standard (furnished by the manufacturer) with assigned reflectance values based on magnesium oxide equal to 100%. A corrector adjustment linked with the photometer diaphragm enables one (if necessary) to linearize the photometric system. The study shows the instrument to be photometrically accurate above 30%; however, the manufacturer recommends that the operator check the linearity of response each time a new light source is installed. This is accomplished through the use of two neutral glass standards of known optical transmission furnished by the manufacturer. The measured effective wavelength of the instrument is not correct for the determination of standard brightness and will change with the use of the instrument due to the instability of the brightness filter. The spectral transmission characteristics of a filter of the type employed will change if subjected to excessive heat (the filter is located too near the light source). The use of a suitable glass filter in the present location in the instrument would minimize the observed spectral change. The observed discrepancies between the reflectance data obtained using the Elko II and the standard brightness tester are attributable to the following factors: (1) the difference in geometry (even though both are 45–0°), (2) the difference in the spectral characteristics, (3) the difference between the two instruments in the relative areas of illumination and viewing, and (4) difference in the standards employed (attributable to the variability of the magnesium oxide scale). Proper use of the "Specific Calibration Procedure" shows that the Elko II correctly indicates the variability of the brightness of paper (for essentially nonfluorescent papers). The instrument is not basically designed for the evaluation of brightness of papers containing fluorescent materials.

LEONARD R. DEARTH, Research Aide, WAYNE M. SHILLCOX, Research Assistant, and J. A. VAN DEN AKKER, Senior Research Associate, The Institute of Paper Chemistry, Appleton, Wis.

THE Zeiss-Electrophotometer Elko II, manufactured by Carl Zeiss, Oberkochen, Germany, is the thirteenth reflection meter studied on the American Paper and Pulp Association's instrumentation program (*1–13*).

Descriptive literature concerning the instrument states: "The electrophotometer Elko II is primarily intended for the measurement of light absorption (extinction) of solutions for the purposes of photometric analysis." Supplementary equipment for reflection measurements have made the instrument adaptable for use as a reflection meter. It has been examined and studied on the APPA instrumentation program as a reflection meter.

Like the standard brightness tester, the instrument employs a 45–0° geometry. A series of eight filters (including a filter designed for brightness measurement) covering the spectral region from approximately 420 to 680 mμ make the instrument adaptable for use in color control of "white" and lightly tinted papers.

Data presented in this report show the correlation of reflectance values obtained using this instrument (employing the blue filter designated for brightness) with brightness values (*14*) obtained using the standard brightness tester.

DESCRIPTION OF THE INSTRUMENT

The Elko II shown in Fig. 1 consists of two units.

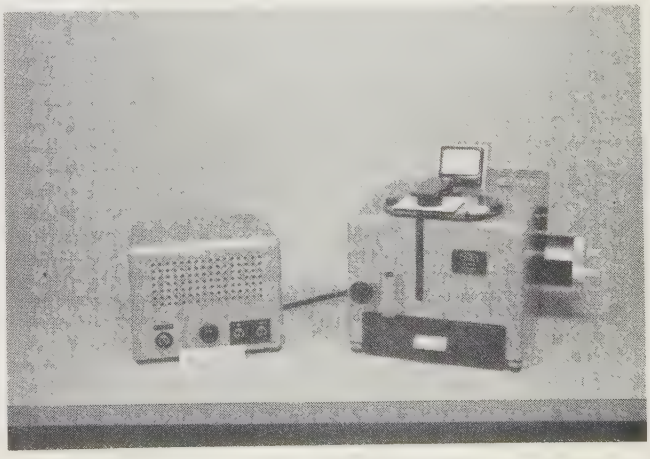


Fig. 1. The Zeiss Elko II

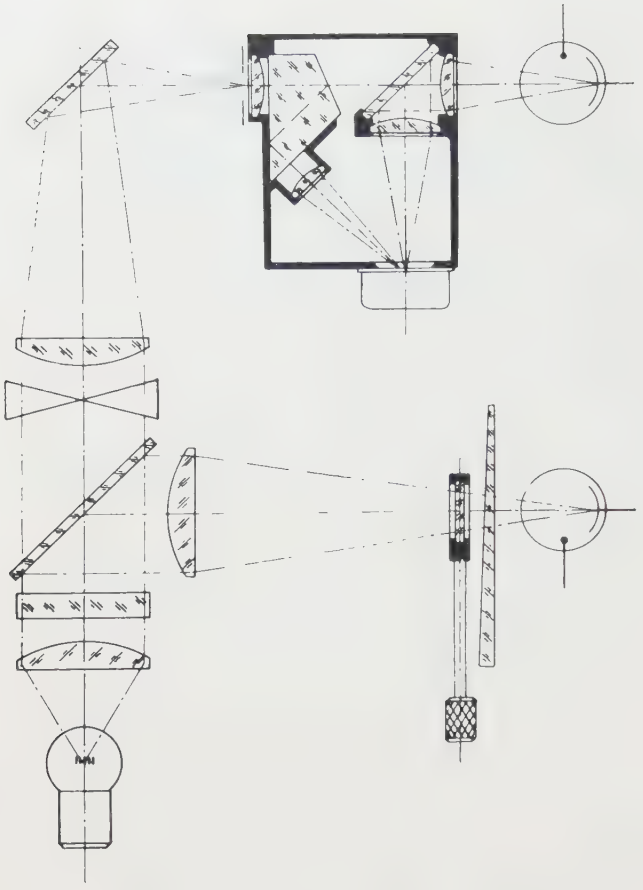


Fig. 2. A schematic diagram showing geometry of the Elko II

The light source (a 12-v., 50-w. incandescent lamp), null indicator, phototubes and amplifier are assembled in one unit and are connected to the power supply by means of a flexible cable. The instrument is designed for use with a 220-v., 50-cycle source. However, the manufacturer furnishes a transformer for use with the the instrument which permits operation on a 60-cycle, 115-v. line. The instrument employs a 45–0° goemetry attained through the use of a lens and prism arrangement. A schematic diagram indicating the light path and the geometry employed is shown in Fig. 2. Another schematic diagram showing the circuitry employed is given in Fig. 3.

The specimen is placed over the aperture (27 mm. diameter) and held in position by a hinged weight of approximately 0.5 kg. Located on the right side of the instrument is the measuring drum. A neutral wedge operated by a knurled knob located on the left side serves to balance the instrument optically. A small knob located on the left front of the instrument serves to balance the instrument electrically. A null indicator, by means of which the balancing is controlled, is positioned on top of the instrument. Eight filters (including the filter designed for use in the brightness measurement) are stored in the drawer located at the bottom of the instrument. The filter selected for a measurement is inserted in a filter holder located directly in front of the lamp housing. If no filter is present in the holder, the light path to the instrument is blocked by an automatically closing shutter.

As shown in Fig. 2, the light from the source passes through a condenser lens, the selected filter, strikes a beam-splitting plate (a portion of the light being directed to the reference phototube) and then passes through the photometer diaphragm to a prism which is designed to direct the light upon the sample (or standard) at an angle of 45°. Light leaving the sample (or standard) in a direction perpendicular to the plane of the sample is collected for measurement.

With both phototubes connected in series in a balanced circuit, only the differential current is amplified and indicated on the null indicator. The instrumental sensitivity can be increased by an appreciable factor by depressing the sensitivity key. Depressing the key increases the resistance in the grid circuit.

The reflectance of the specimen is compared with that of the standard. The manufacturer furnishes a standard (opal glass, 35 mm. diam.) calibrated against magnesium oxide for use with all of the filters.

STUDY OF INSTRUMENTAL VARIABLES

Effects of Changes in Line Voltage and Line Frequency

The Elko II is normally intended for use with a 220-v., 50-cycle source. The manufacturer furnishes a transformer for use with the instrument which permits operation on a 60-cycle, 115-v. line. He states that the performance and accuracy of the instrument is independent of large variations in line voltage.

A variable-frequency alternator was employed for both voltage and frequency study. With the line voltage to the instrument being held constant at 115 v. and the measuring drum adjusted to the assigned value of the standard, the line frequency was varied in one-cycle steps from 58 through 62 cycles per sec. Then, with the line frequency held constant at 60 cycles per sec., the line voltage was varied in 5-v. steps from 105 through 125 v.

The instrumental response is independent of frequency in the range, 58–62 cycles per sec., and of voltage in the range, 105 to 125 v.

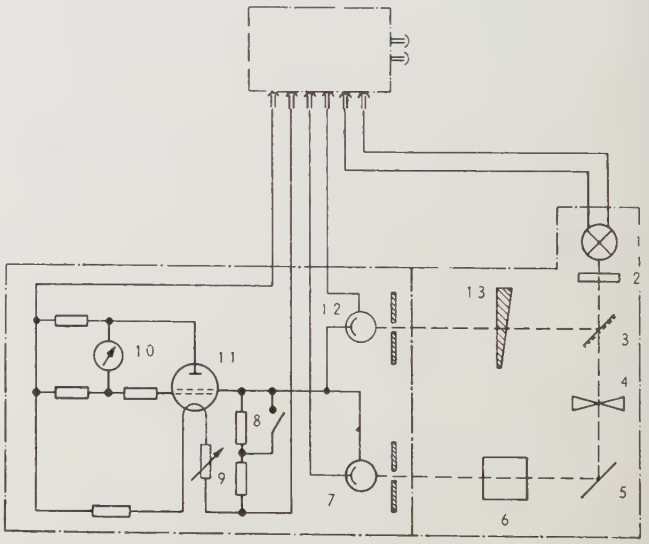


Fig. 3. A schematic diagram showing circuitry of the Elko II

1—lamp; 2—filter; 3—beam-splitting plate; 4—photometer diaphragm; 5—mirror; 6—specimen; 7 and 12—phototubes; 8—sensitivity key; 9—zero-point regulator; 10—null indicator; 11—amplifier tube; 13—neutral wedge.

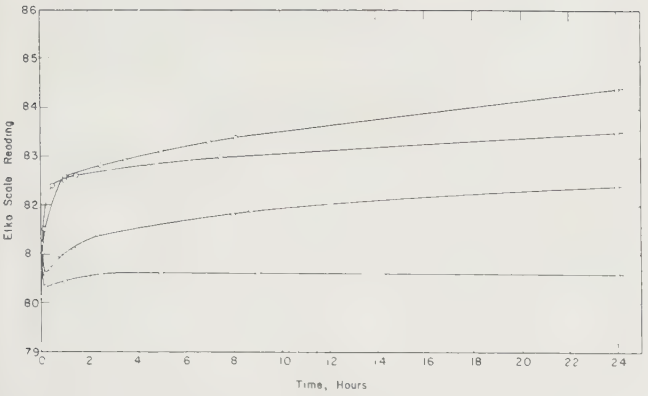


Fig. 4. Dependence of Elko II scale reading on instrumental drift

Linearity of Response

A corrector adjustment mounted on the right side of the instrument and linked with the photometer diaphragm makes it possible to linearize the relationship between the measuring drum reading and the photometric system. The adjusting device, comprised of two corrector scales is covered by a protecting cap. Each individual tungsten lamp is correlated with a definite setting of the corrector scales. For lamps supplied with the instrument, the corrector settings are determined by the manufacturer and are recorded on a test card on the inside of the protector cover. If proper adjustment of the correctors is not known for a lamp, it can be ascertained through the use of two neutral glass standards supplied by the manufacturer. The transmission values of the neutral standards are given by the manufacturer (in the present case, 25 and 50%).

The linearity of response of the instrument was checked with the corrector adjustment setting as received. The method used in this study employed a zero external resistance circuit with a blocking layer photocell and a sensitive galvanometer and a series of neutral screens. The neutral screens were fabricated in such form that they could be inserted in the light beam after its passage through the photometer diaphragm. A piece of opal glass was used as a diffusing light transmitter for the blocking layer photocell and as a standard for use in establishing the "100 point" of the Elko II.

Before inserting the neutral screens, the "100 point" on the galvanometer was established. The neutral screen was then inserted into the light beam and a reading on the galvanometer was obtained. Without disturbing the screen setting, the null indicator was adjusted to zero by means of the gray wedge. The screen was then removed and the null indicator was again adjusted to zero by means of the measuring drum. Ten readings were obtained for each of the individual screens following this procedure. The points on the scale which were found to be accurate were 37, 42, 65, and 82. The deviations from linearity at 15 and 21 were 0.4 and 0.3% respectively.

The inaccuracy of the method of determining the linearity of response is of the order of 0.1%. The photometer diaphragm does not at any time completely close, thereby making it impossible to check the instrumental zero.

Table I. Effects of Changes in Ambient Temperature on Elko II Reading[a]

Time, hr.	*Temperature, °F.*	*Elko II reflectance, %*	*Difference*
...	77	81.2	...
0.08	85	81.2	0.0
0.33	92	81.2	0.0
0.83	98	81.1	−0.1
1.50	101	81.1	−0.1
2.83	103	81.4	+0.2
3.08	98	81.4	+0.2
3.20	94	81.4	+0.2
3.42	93	81.4	+0.2
3.66	92	81.3	+0.1
3.92	90	81.3	+0.1
4.33	88	81.3	+0.1
4.58	87	81.3	+0.1
5.17	85	81.3	+0.1
6.25	80	81.3	+0.1
6.50	78	81.3	+0.1

a The instrument had been in continuous operation for a 24-hr. period prior to performing the temperature study.

Table II. Effects of High Relative Humidity Upon Elko II Reading[a]

Time, hr	*Temperature, °F.*	*Elko II reading*	*Difference*
...	90	81.2	...
0.17	91	81.1	−0.1
0.33	93	81.1	−0.1
0.67	93	81.2	0.0
0.92	93	81.3	+0.1
1.25	94	81.4	+0.2
1.83	95	81.7	+0.5
2.17	96	81.8	+0.6
3.17	96	82.1	+0.9
4.17	96	82.1	+0.9

a The instrument had been in continuous operation for a 24-hour period, in a dry atmosphere, prior to performing the humidity study. The room relative humidity was approximately 80%.

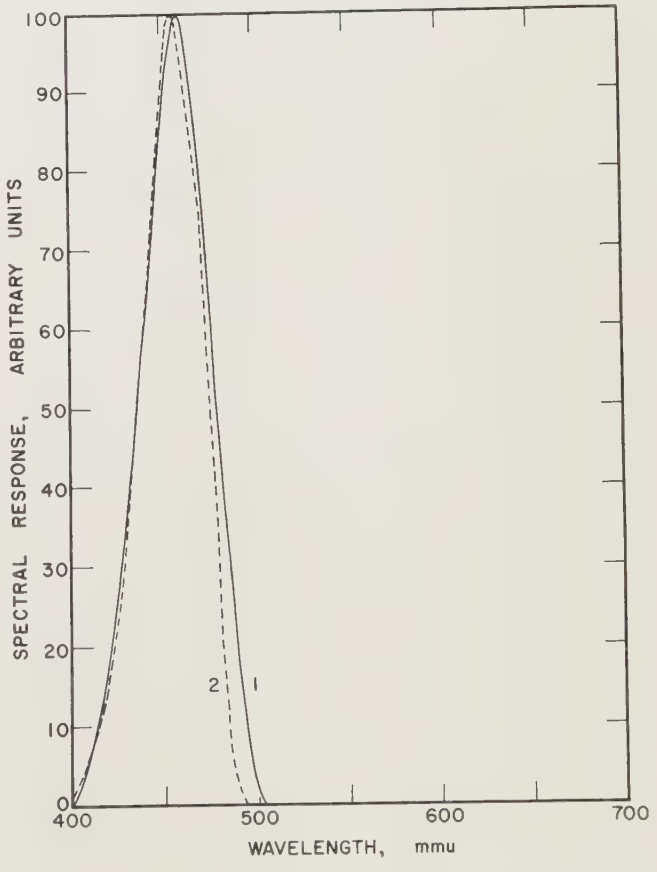


Fig. 5. Spectral response

1--IPC standard brightness tester; 2—Elko II.

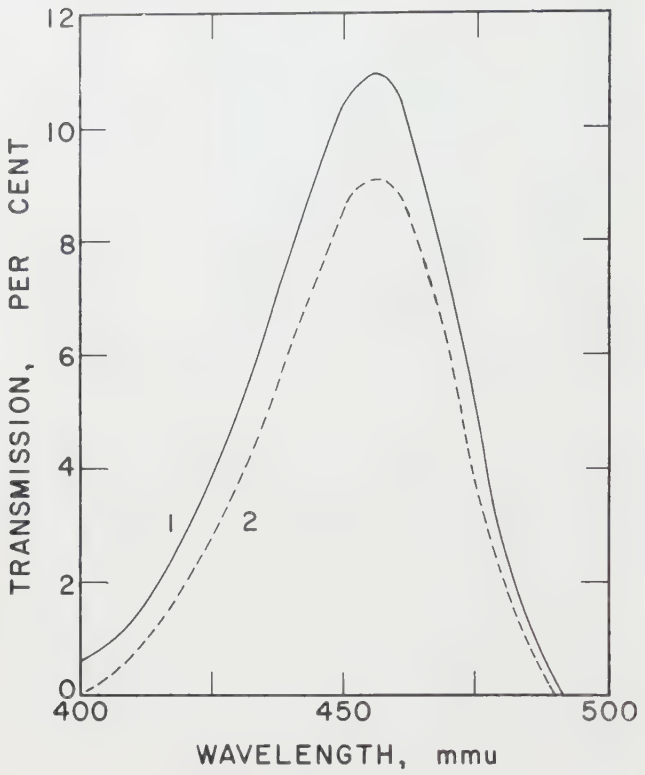


Fig. 6. Spectral transmission curve for Elko II brightness tester

1—spectral transmission characteristics of filter as received; 2—spectral transmission characteristics of filter near completion of study.

Effects of Instrumental Drift and Changes in Ambient Temperature

There is no recommended warm-up period for the Elko II. After the instrument is electrically and optically balanced, it is suggested that the instrument sensitivity be checked to be certain the instrument is functioning properly. A deflection of at least five scale divisions on the null indicator for a 1% change in the diaphragm opening indicates that the instrument is functioning normally.

The drift characteristics were studied starting immediately after the instrument had been electrically and optically balanced and observations were continued for approximately a 24-hr. period.

Four individual drift studies were performed at room temperatures ranging from 70 to 85°F. Without further adjustment of the instrument settings, readings were obtained at varying intervals over each 24-hr. period. The data obtained are shown in Fig. 4.

The variation between the individual drift curves probably is attributable to the changes in the room temperature; however, if one follows the proper procedure for obtaining reflectance data, the observed drift should not impair accuracy, if the instrument has been "on" for at least 15 min.

The effects of changes in ambient temperature upon the Elko II reading were determined by rapidly raising the room temperature from 77 to 103°F. After allowing the instrument to reach equilibrium at the higher room temperature, the room was cooled rapidly to approximately the original temperature. The instrument had been in continuous operation for 24 hr. prior to beginning the temperature study and was electrically and optically balanced. Reflectance readings obtained at varying intervals over the period are given in Table 1.

Effects of High Relative Humidity Upon Elko II Reading

A drying cartridge is installed in the instrument to minimize difficulties that may arise because of very humid conditions. It seemed desirable, because of the high value of the grid resistance, to observe the performance of the instrument under extreme humidity.

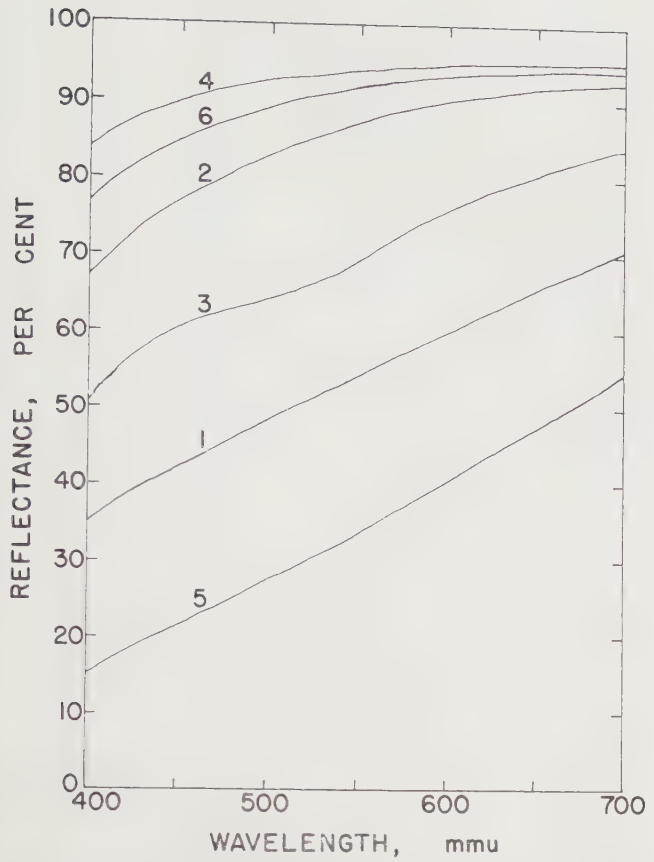
For this study, the instrument was moved rapidly from room conditions of 95°F. and 25% relative humidity into a room controlled at 95°F. and 80% R.H. Reflectance readings were obtained at frequent intervals over a 4-hr. period; these are presented in Table II. It will be seen that the instrumental drift corresponding to the short period of time required to compare a sample and standard is satisfactorily small.

Spectral Response

The over-all instrumental spectral response for the Elko II "as received" was determined by obtaining the product of the spectral response of the phototube (S-4 response), the transmission curve for the blue filter (brightness filter), the spectral characteristics of the infrared absorbing filter, and the relative spectral energy distribution of the lamp (determined for a tungsten filament lamp at 3000°K). The spectral response data for the phototube and the spectral characteristics of the infrared stopping filter were furnished by the manufacturer. The relative spectral response curves for the Elko II and the standard brightness tester are shown in Fig. 5. The form of the spectral response function for either instrument is determined largely by the transmission characteristics of the blue filter employed. The spectral transmission curve for the Elko II brightness filter obtained shortly after receiving the instrument is shown in Fig. 6. The filter in its

Table III. Description of Samples Used in the Comparison of Elko II Reflectance with Standard Brightness

Sample no.	*Description*	*Standard brightness, %*
1	Unbleached hardwood kraft handsheet	42.0
2	Bleached hardwood kraft handsheet	74.4
3	Unbleached softwood sulphite handsheet	57.7
4	Bleached softwood sulphite handsheet	86.8
5	Unbleached softwood kraft handsheet	21.3
6	Bleached softwood kraft handsheet	81.4
7	Bleached softwood soda handsheet	73.5
8	Bleached hardwood sulphite handsheet	82.3
9	Uncreped facial tissue	78.4
10	Commercial unbleached kraft	23.5
11	Commercial groundwood	47.5
12	Bleached manila liner stock	55.4
13	White patent coated board	77.6
14	Uncoated book paper	70.0
15	Machine-coated book paper	79.3
16	Titanium-filled paper (3.56% filler)	85.2
17	Wrapping tissue paper	72.0
18	Creped facial tissue	75.0
19	24-lb. unwaxed bread wrap	75.4
20	24-lb. waxed bread wrap	64.3
21	Newsprint paper	60.9
22	Commercial bond	80.3
23	Commercial bond with a fluorescent whitening agent added	92.6
24	Ledger paper	76.4
25	Cast-coated paper	89.5
26	Titanium oxide	95.4
27	Pure calcium carbonate	98.3
28	Whatman no. 1 filter paper	89.0
29	Whatman no. 1 filter paper with a fluorescent agent added	97.3
30	Commercial clay	77.0



Figs. 7. Spectral reflectivity curves for samples described in Table IV

present location in the instrument is subjected to excessive heat. Past work has shown that the spectral transmission of filters of this type subjected to excessive heat do change with age. Toward the completion of the instrumentation study, another spectral transmission curve was obtained for the Elko II brightness filter and this is also shown in Fig. 6. The observed change in the transmission characteristics of the filter is large considering the short period of use in the instrument and is indicative of the magnitude of change one might expect for an extended period of operation.

The effective wavelength of the Elko II as received was determined employing glass filters having nearly linear slopes (*15*). If an instrument is photometrically accurate, the effective wavelength determined with a filter having a transmission curve of negative slope should agree with that obtained using a filter having a transmission curve of positive slope.

The measured effective wavelengths, determined with filters having transmission curves of positive and negative slopes, were the same, at 455.5 μ. Near the completion of the instrumentation study, the effective wavelength had increased to 456.6 μ.

Comparison of Elko II Reflectance Values with Standard Brightness

The reflectance measurement is made by the substitution procedure. The specimen is first placed over the aperture (held in position by the hinged weight) and the measuring drum is set at the value of the standard. The null indicator is then balanced by means of the gray wedge. The specimen is then replaced with the standard and the null indicator is again balanced by means of the measuring drum. The manufacturer furnishes an opal glass standard (35 mm. diam.) evaluated against magnesium oxide for use with all of the filters.

Reflectance data were obtained with the Elko II using three different means of standardization for a series of papers and fillers described in Table III. Spectral reflectivity curves for the individual papers and fillers (excluding the papers containing a fluorescent agent) were obtained using the General Electric Recording Spectrophotometer (GERS) and are shown in Figs. 7 to 11.

The first set of data, presented in Table IV, were obtained using the standard supplied by the manufacturer. The standard brightness values were obtained for the same series of samples and are also given in this table. The observed discrepancies between the two sets of data for the essentially nonfluorescent papers can be attributed to the geometric and spectral differences between the two instruments, to difference between the standards, and to the difference between the two instruments in the relative areas of illumination and viewing. The reflectance values obtained for the translucent and lightweight papers (tissues) are critically dependent upon the relative size and shape of these areas. The geometry employed was not studied; however, the method employed by the manufacturer for establishing the desired geometry should not be difficult. An instrument employing this type of geometry requires that the area surrounding the specimen opening be flat to within very small tolerances if accurate and reproducible data are to be obtained. This area in the case of the Elko II is flat when the instrument is cold but deviates from flatness (because of warming) during operation. The low Elko II reflectance values for the papers containing a fluorescent material are attributable to the

Table IV. Comparison with Standard Brightness of the Elko II Reflectance, Determined Using the Standard Furnished by the Manufacturer

Sample no.	*Standard brightness, %*	*Elko II reflectance, %*	*Difference*
1	42.0	42.7	+0.7
2	74.4	75.9	+1.5
3	57.7	58.7	+1.0
4	86.8	88.6	+1.8
5	21.3	21.7	+0.4
6	81.4	82.5	+1.1
7	73.5	74.6	+1.1
8	82.3	83.5	+1.2
9	78.4	81.9	+3.5
10	23.5	23.6	+0.1
11	47.5	48.3	+0.8
12	55.4	55.5	+0.1
13	77.6	77.2	−0.4
14	70.0	70.9	+0.9
15	79.3	80.1	+0.8
16	85.2	86.1	+0.9
17	72.0	74.4	+2.4
18	75.0	79.3	+4.3
19	75.4	76.4	+1.0
20	64.3	64.3	0.0
21	60.9	61.1	+0.2
22	80.3	81.1	+0.8
23[a]	92.6	88.8	−3.8
24	76.4	77.2	+0.8
25	89.5	90.2	+0.7
26	95.4	96.2	+0.8
27	98.3	98.9	+0.6
28	89.0	90.7	+1.7
29[b]	97.3	91.7	−5.6
30	77.0	78.1	+1.1

[a] Commercial bond with a fluorescent agent added. Evaluated on the felt side.
[b] Whatman no. 1 filter paper with a fluorescent agent added.

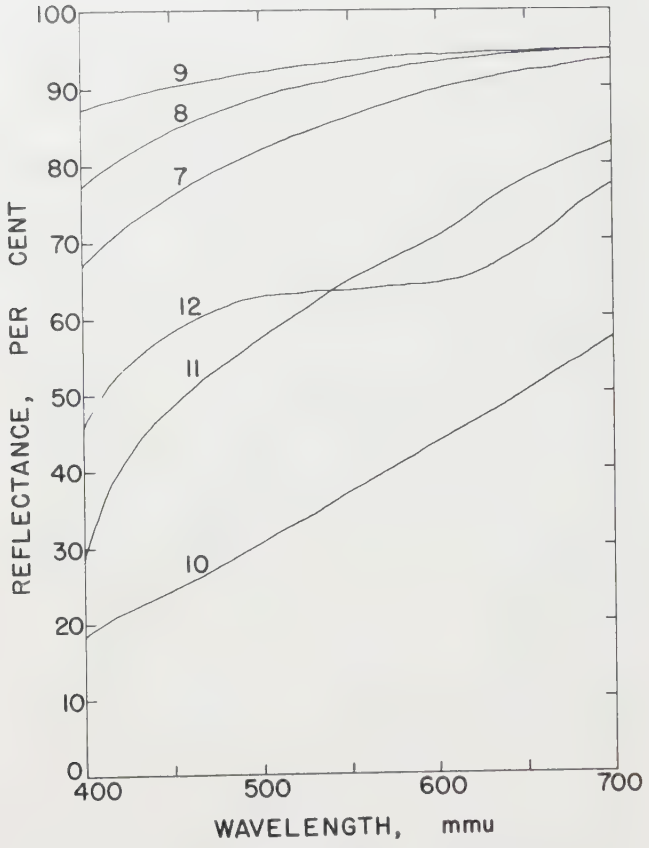


Fig. 8. Spectral reflectivity curves for samples described in Table IV

fact that, in this instrument, the blue filter is in the incident beam and, accordingly, this beam contains no near-ultraviolet light to excite fluorescence.

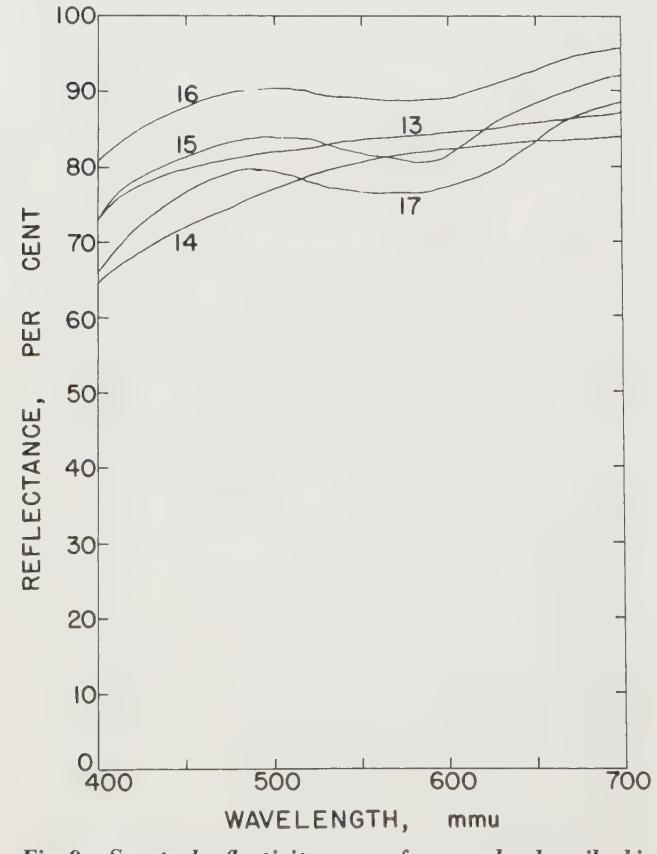


Fig. 9. Spectral reflectivity curves for samples described in Table IV

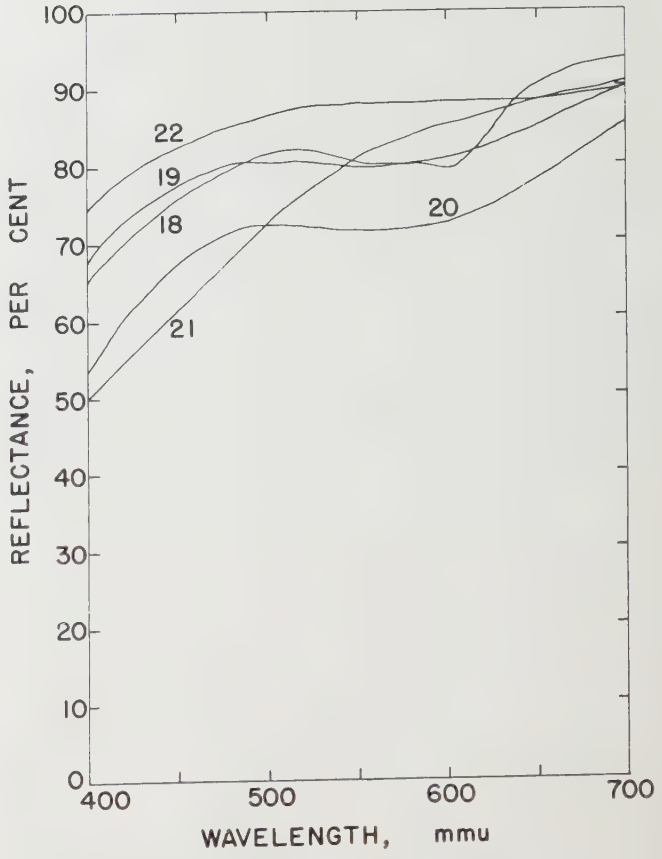


Fig. 10. Spectral reflectivity curves for samples described in Table IV

A second set of data (Table V) were obtained using as a standard on the Elko II an enameled steel plaque with an assigned value based on the standard bright-

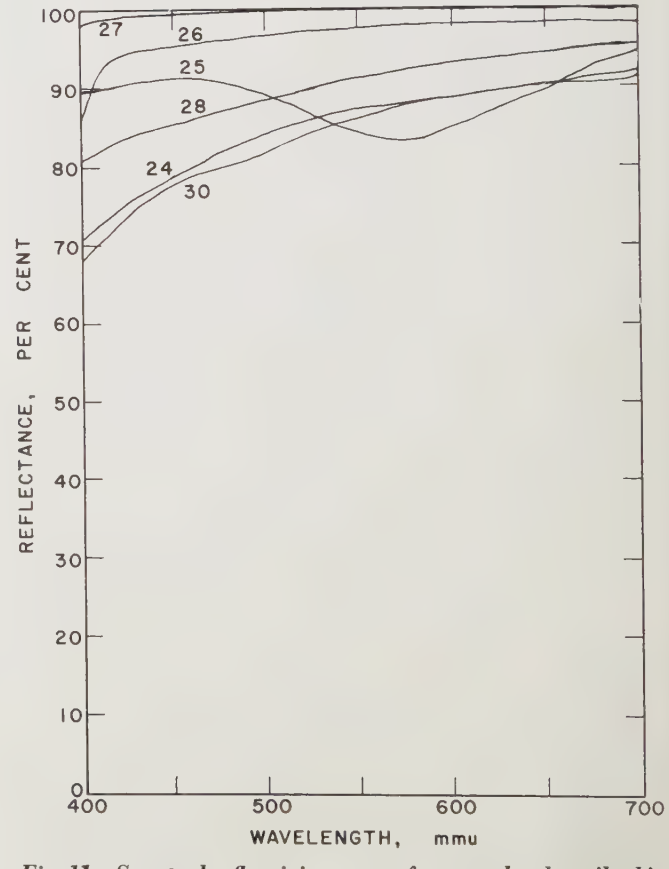


Fig. 11. Spectral reflectivity curves for samples described in Table IV

Table V. Comparison with Standard Brightness of Elko II Reflectance, Using a Standard Evaluated with the I.P.C. Master Brightness Tester

Sample no.	*Standard brightness, %*	*Elko II reflectance, %*	*Difference*
1	42.2	43.1	+0.9
2	74.6	76.4	+1.8
3	57.8	59.1	+1.3
4	87.0	89.4	+2.4
5	21.2	22.0	+0.8
6	81.4	83.4	+2.0
7	73.8	75.1	+1.3
8	82.3	84.2	+1.9
9	78.7	82.5	+3.8
10	23.7	23.7	0.0
11	47.5	48.6	+1.1
12	55.5	55.8	+0.3
13	77.5	77.4	−0.1
14	70.0	71.3	+1.3
15	79.3	80.6	+1.3
16	85.3	86.8	+1.5
17	72.3	74.0	+1.7
18	74.8	80.2	+5.4
19	75.4	76.9	+1.5
20	64.2	64.5	+0.3
21	60.9	61.6	+0.7
22	80.3	81.7	+1.4
23[a]	92.6	89.3	−3.3
24	76.5	77.8	+1.3
25	89.5	90.9	+1.4
28	89.2	91.3	+2.1
29[b]	97.5	92.4	−5.1

[a] Commercial bond with a fluorescent agent added. Evaluated on the felt side.
[b] Whatman no. 1 filter paper with a fluorescent agent added.

ness scale. The differences are still too large to permit the measurement of brightness of papers with the Elko II using a single standard based on the standard brightness scale.

A third set of data, presented in Table VI, were obtained for essentially nonfluorescent papers employing the "Specific Calibration Procedure" (*10*). Standardization in this manner accounts for variations in the spectral, photometric and geometric characteristics between the instruments and permits the accurate measurement of brightness based on the standard brightness scale. The data show good agreement between the Elko II reflectance values and the standard brightness data. However, the Specific Calibration Procedure should not be used with the Elko II when fluorescent materials are involved (*12*). As mentioned earlier, the blue filter of the Elko II is located in the incident beam. This eliminates the near-ultraviolet radiation and thus there is very little energy present to to excite fluorescent materials. Also, the receptor views the entire spectral region in accordance with the response of the phototube and any fluorescent radiation appearing in *any* portion of the visible spectrum would be sensed by the phototube.

Table VI. Comparison with Standard Brightness of Elko II Reflectance, Determined in Accordance with the Specific Calibration Procedure, for Essentially Nonfluorescent Papers

Sample no.	*Standard brightness, %*	*Elko II reflectance, %*	*Difference*
10	23.4	23.5	+0.1
11	47.5	47.5	0.0
13	77.5	77.5	0.0
16	85.3	85.4	+0.1
25	89.6	89.6	0.0

COLOR CONTROL WITH THE ELKO II

The Elko II is equipped with eight filters (including

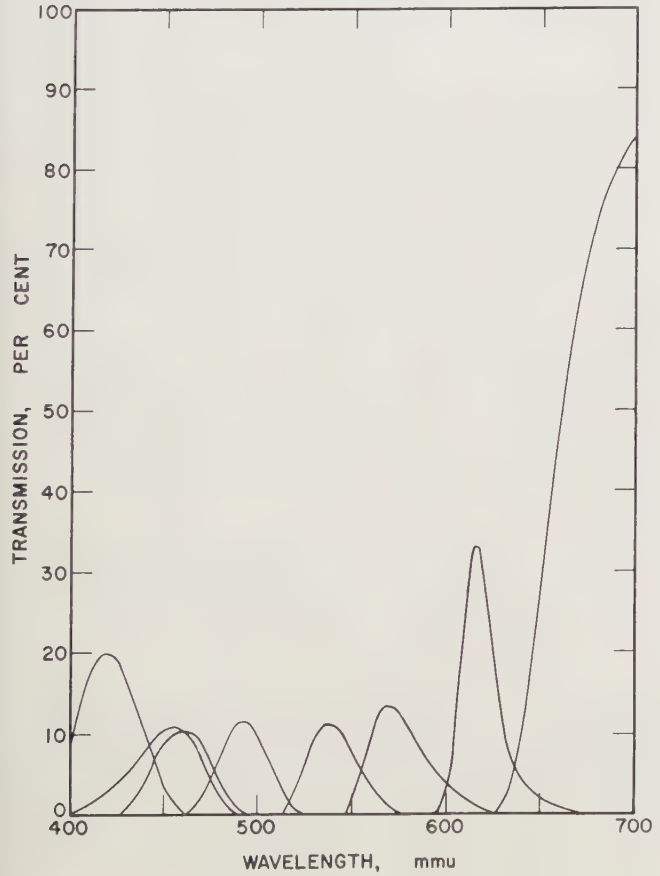


Fig. 12. Spectral transmission curves for series of filters supplied with the Elko II

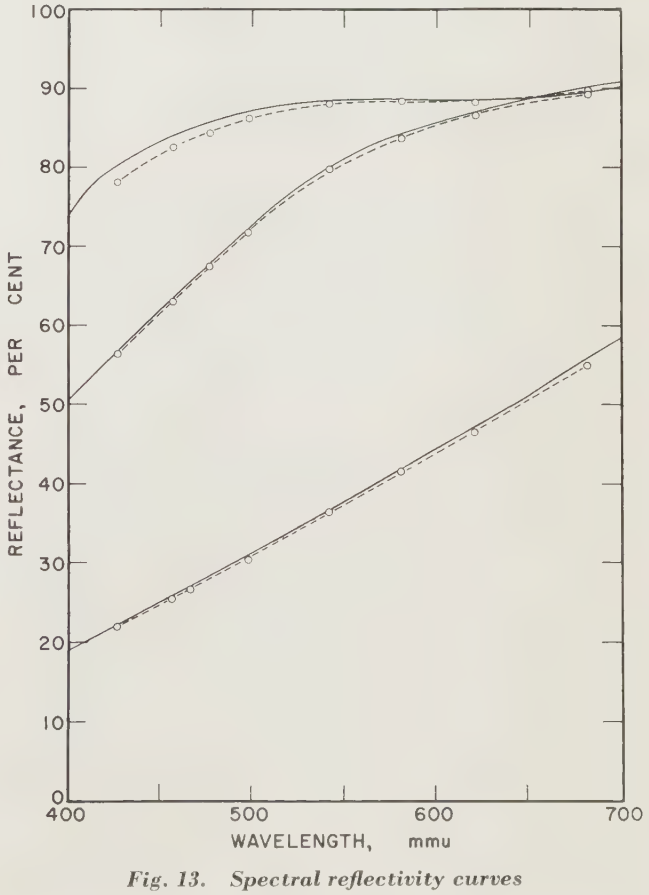


Fig. 13. Spectral reflectivity curves
——— GERS; - - - - Elko II.

the filter employed for brightness measurement) covering the visible spectral region from approximately 420 to 680 μ; this makes it adaptable for use in color control, particularly for "white" and lightly tinted papers.

The spectral transmission curves for the individual filters (obtained using the GERS) are shown in Fig. 12. Spectral reflectivity curves obtained for several papers (nonfluorescent) using the Elko II and the GERS are shown in Fig. 13. The points plotted in Fig. 13 are not at the wavelengths quoted by the manufacturer but rather at the "effective wavelengths" determined in the present study (the plotted points differ from the quoted wavelengths by several millimicrons).

Although the spectral reflectivity curves determined with the Elko II differ from those determined using the GERS (due to spectral and geometric differences) the curves are similar in shape, and *differences* obtained using the Elko II should be in close agreement with differences obtained using the GERS or a similar instrument for "white" and lightly tinted papers.

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Literature Survey on the Cold Soda Pulping Process

J. R. BYRNE and M. H. VOELKER

This is a survey of the literature published on cold soda pulping from 1950 as reported in the *Abstract Bulletin of The Institute of Paper Chemistry* and *Chemical Abstracts* through August, 1959. For the purpose of this survey, the cold soda process has been defined as any pulping process using caustic soda at atmospheric pressure up to a temperature of 100°C. Therefore, there have been included references to pulping processes in which caustic soda is used as one of several treatment stages and in which caustic soda is used in combination with other chemicals to make up a liquor for single-stage treatments.

COLD SODA PULPING—GENERAL

Wells and Stone (*1–4*), in their continuing alkaline pulping reviews from 1950 through 1953, made several references to the cold soda process. The process is included in an Institute of Paper Chemistry Bibliographic Series number by West (*5, 6*). Wells (*7*) presents an outline of the development of high-yield semichemical pulping methods including the cold soda process. Runkel (*8*) reviews past work and presents a survey of the present semichemical pulp situation. Converse (*9*) describes three commerical semichemical processes: the neutral sulfite, sulfate, and cold caustic processes. Rotary, vertical, and continuous digesters can be used with the refining generally accomplished in disk refiners. Certain characteristics of semichemical pulps of importance when designing the system are pointed out.

Surewicz (*10*) discusses the technical procedures followed, pulp yields and pulp properties obtained, production costs, and recovery of chemicals in the chemigroundwood processes. The development trends of these processes in Europe are indicated.

Wultsch (*11*) describes and critically discusses various semichemical pulping processes. Runkel and Patt (*12*) review the wide range of pulps lying between straight groundwood and fully chemical pulps in a monograph on semichemical pulps. The history and development of semichemical pulping is recalled and the present status is outlined.

Kleinert (*13*) surveys the progress in wood pulping processes for the production of high-yield chemical and semichemical pulps with special consideration of the research contributions made by the Pulp and Paper Research Institute of Canada.

Šedivý and Svatoň (*14*) report that semichemical pulps made by the cold soda process are some of the new materials utilized in the manufacture of newsprint to replace softwood sulfite and mechanical pulps. The composition of newsprint made from blends of this and other types of pulp is discussed.

The Food and Agriculture Organization of the United Nations (*15*) presents a study of pulping processes for fibrous raw materials from new sources. Of particular interest are the cost data sheets showing estimated production costs of various raw materials by different processes.

McGovern (*16*) discusses the three major objectives of the U. S. Forest Products Laboratory's research on semichemical pulping and reviews past activities and results. The recently developed cold soda process and the possibilities of this new method are discussed. McGovern (*17*) also presents a review of semichemical pulping with emphasis on the scope, history, development, fibrous materials, pulping and bleaching procedures, manufacturing practice, and uses for semichemical pulp.

Grant (*18*) describes and compares the merits of several nonconventional pulping processes including the Lathrop and Aronovsky method. Brounstein (*19*) presents a review of lesser-known pulping methods including acidic, alkaline, and neutral systems, and those which involve halogen compounds.

Chemical Engineering (*20*) presents a summary of chemical process and engineering developments which were announced or commercialized during 1953–54, including a section on pulp and paper. Janes (*21*) surveys the relatively recent processes in pulping that are in use today. The advantages and disadvantages of some of the semichemical processes is one of the main topics covered in the discussion.

Paper Mill News and *Paper Trade Journal* (*22*) report on a cold soda pulping demonstration presented at an American Paper and Pulp Association Coordination of Research meeting. *Paper Trade Journal* (*23*) reports on a symposium prepared from the general discussion of semichemical pulping at the annual pulp and paper conference held at the University of Florida. Two of the topics covered were continuous caustic treatment and cold soda process for corrugating medium.

Bugg (*24*) presents a supplementary report on cold soda pulping which outlines in summary form results obtained in the plant for an output of 65 long tons of oven-dry cold soda pulp per day. The cold soda plant has been raised to its designed capacity by the addition of three new refiners.

Baird, *et al.* (*25*) present comparative data on two countercurrent systems for the re-use and recycling of pulping liquors and wash waters in the cold soda pulping of aspenwood. An accelerated batch pulping process was used in both systems; one wash system utilized only 13% of the volume of the fiberizing liquor from the previous cycle and the other was completely closed.

THE PULPING PROCESS

Green Bay Paper and Pulp Company (*26*) developed a cold caustic process for producing pulp which can be

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used for corrugating medium. In the process, wood chips are soaked in 2.5% caustic liquor at room temperature for 2 to 3 hr. Pulp yields are frequently as high as 90%. Barker (*27*) reports that the Stone Container Corp. division in Coshocton, Ohio, has been using the cold soda process for producing corrugating medium since 1956. The pulp is augmented by slushed waste corrugated stock to make up the furnish. The operation and mill equipment are outlined.

Bauer (*28*) describes the Bauerite chemimechanical pulping process. The process produces pulp yields of 87 to 92% from New England hardwoods with a pretreatment of 3 to 4% cold caustic. The strength of the pulp varies from that of very good spruce groundwood to 50% stronger than book grade groundwood. Meinhold and Luethi (*29*) report that the Gould Paper Co., New York is producing groundwood by the Bauerite process. The pulp is being used as a substitute for spruce groundwood, to which it is reported to be superior in Mullen, tear, and tensile values. At a freeness of 300 to 150 ml., the pulp is equivalent in strength to spruce groundwood at 90 ml. freeness. Evans (*30*) and Snyder and Premo (*112*) also present step-by-step descriptions of the process at Gould Paper.

Brown (*31*) reviews the result of recent research on the penetration of caustic soda liquor into chips and discusses their significance for the improvement of the cold soda pulping process. It was found that the rate of diffusion of caustic liquor can be accelerated by either pre-evacuating the treating vessel, increasing the hydrostatic pressure during steeping, or decreasing the chip size. The addition of surfactants also accelerates liquor penetration.

McGovern (*32*) reports that the cold soda pulping process has successfully established itself commercially in the medium of continuous flow pulping processes. Descriptions and evaluations are given of the continuous methods for the treating stage of the process. Dunning (*33*) describes a continuous multistage impregnation process in which wood chips are mixed with partially spent caustic solution from the second stage FiberPress in a mixing conveyor ahead of a Sprout-Waldron chip fractionator. The resultant smaller chips together with the partially spent caustic solution are then conveyed to the first FiberPress for a preliminary impregnation with caustic. The partially impregnated wood particles are mixed with fresh makeup caustic and are conveyed to the second press for final impregnation, fiberizing, and removal of partially spent liquor. The fiberized pulp is then refined in disk refiners.

Heritage and Van Beckum (*34*) obtained a patent in 1951 for a process in which the raw material is treated with a 0.6% aq. NaOH solution at 20 to 140°C. Two products are obtained: a fibrous residue and, by adjusting the pH, lignin. The inventors were awarded two more patents (*35, 36*) in 1954 for a process which is a continuation-in-part of the 1951 patent. In the process, mechanically comminuted wood fibers are treated successively with caustic, hypochlorite, and caustic at atmospheric pressure and a temperature up to 140°C. By careful control of conditions, lignin and polysaccharides are extracted and separated from the cellulosic material. The second patent concerns itself particularly with the third step of the treatment.

Heritage (*37*) obtained a Canadian patent for a process in which the raw wood fiber is steamed at 100 to 175 p.s.i. for 1 to 11 min. and then subjected to the action of a 0.1 to 3.75% aq. NaOH solution for 0.5 to 2 hr. at about the boiling temperature of the solution. The resulting pulp is suitable for use in the production of hardboard or paper. In another patent by Heritage (*38*) the caustic-extracted pulp prepared as in the previous patent is subjected to the action of chlorine and then extracted again with 0.1 to 3.75% NaOH solution at the boiling point.

Ohlin (*39*) obtained a patent for a process in which finely divided wood is impregnated with a sodium hydroxide solution at a temperature of 80 to 100°C. and at ordinary pressure. The mass is then ground for at least 10 min. and neutralized stepwise by means of gaseous sulfur dioxide, sulfurous acid, or an acid sulfite to obtain a neutral solution which sulfonates and plasticizes the lignin and exposes the fibers.

Successful test runs have been completed on the new Black-Clawson continuous cold soda pulping system (*40*). The system is reported to produce pulps of exceptionally high quality from hardwood chips in a wide range of freeness and with low horsepower consumption.

Rys (*41*) obtained patents for a process for delignifying fibrous materials by soaking them at room temperature in an aqueous solution of sodium chlorate, removing the excess solution, and contacting the impregnated material with gaseous hydrogen chloride at a temperature below 75°C. The actual removal of lignin is accomplished by subsequent alkaline extraction.

A description is given (*42*) of the cold soda process along with a discussion of the advantages of the process and the uses of cold soda pulps.

Renteln (*43*) received a patent for treating mechanical pulp to activate the bonding ability between the fiber aggregates and the fiber fragments to increase the strength properties of the resulting products. The pulp is subjected to a weak alkaline solution having a concentration between 0.01 and 0.8% NaOH at 90 to 100°C. The pulp obtained is claimed to be comparable to semichemical pulp.

Marpillero (*44*) discusses the use of activated chlorate in the pulping of wood and yearly plants. The process consists of two steps, both carried out at temperatures below 90°C. and at atmospheric pressure. The first step is an alkali treatment similar to a cold caustic treatment. The second is performed by submitting the material from the caustic treatment to an activated chlorate treatment. Fiberizing follows in simple conical refiners.

Michon (*45*) patented a process in which wood chips are treated with alkaline cooking liquor at about 100°C. for 0.5 hr. The treated chips are then cooked at 170 to 180°C. for about 0.5 hr.

A chemimechanical process is described (*46*) in which the chips are pretreated in a rapid-cycle digester with cold caustic or hot sulfite, reduced to shives in a high-pressure press, and processed by the conventional train of refiners, screens, and cleaners. Pulp is obtained in a yield of 88 to 92% and of a strength equal to or greater than conventional groundwood pulp.

Figuerola and Gomez (*47*) obtained a patent for a process in which the raw material is treated with a

1 to 2% NaOH solution at 70 to 95°C. and at about 0.5 atm. for 20 to 180 min. The material is then crushed, homogenized, and shaped into boards.

Grand (*48*) describes his own Isograd process for producing chemical pulp from the most heterogeneous mixtures of hardwoods and softwoods. The wood is defibered, screened, and then delignified with a weak alkaline solution at 80°C. Subsequently, a special chlorinating solution produces soluble chlorolignins which are then removed in a tower. Excellent results have been reported for a mixture of French firewood and charcoal wood and for a mixture of 13 Amazonian woods of very different densities. Winczakiewicz (*49*) also describes the Isograd process and reports that experiments in which pulps obtained from hardwoods growing in Venezuela and Argentina were used for the manufacture of offset printing and typewriting papers gave encouraging results.

Aronovsky and Lathrop (*50*) obtained a patent for a mechanochemical process for producing pulp in which the raw material is subjected to the action of sodium hydroxide in solution at a temperature of 90 to 100°C. and at atmospheric pressure. Simultaneous with the chemical action, the material is subjected to vigorous noncutting impact blows while submerged in the pulping liquor, the blows comprising mechanically induced cycles of expression and absorption. The blows are continued for 30 to 60 min. Atchison (*51*) outlines the advantages of the process. A patent for a modified process was obtained by the inventors (*52*) in which the pulping is carried out in three stages to reduce the power requirement.

Magnuson (*53, 54*) obtained a U. S. and a Canadian patent for a process in which chips are soaked at room temperature for 4 to 28 hr. in an aqueous solution of alkaline inorganic pulping reagents, and then digested by the Asplund process using a steam atmosphere at approximately 150 to 170°C.

Jones and Scott (*55, 56*) patented a process for producing cellulose which consists of impregnating the raw material with a 2 to 5% aqueous solution of caustic soda, lowering the temperature until all the water present is frozen and keeping the temperature constant for 1 to 5 hr., raising the temperature to melt all the ice formed, removing the greater part of the alkali solution and then subjecting the material to a delignifying treatment.

PULPING OF AGRICULTURAL RESIDUES, GRASSES, SAWDUST, ETC.

The production of high-tensile strength fibers for use in the manufacture of rope or cloth is the subject of a patent by Stephanus and Rinse (*57*). Agave or manila hemp fibrous masses are soaked in a mixture of zinc oxide and sodium hydroxide in water at room temperature. The fibers are then pressed, washed, dried, and mechanically processed.

Bensano (*58*) obtained a patent for a process where ground parts of plants or vegetables are cooked at normal pressure with 5 to 10% NaOH and then mechanically treated and bleached. Venturini and Dubienski (*59*) received an Italian patent for a process for treating wood chips or straw with sodium carbonate and sodium hydroxide with an excess of gaseous sulfur dioxide added. After 30 to 60 min., the chips are again treated with caustic and sulfur dioxide and heated to 100°C. Sastre and Beltram (*60*) patented a process for producing paper pulp from reed grass. About 2 tons of reed grass is macerated for one day after treatment in a solution of 60 kg. of sodium hydroxide, 25 kg. of calcium chlorate, and water. The process is about 50% efficient, and the digestion can be speeded up by operating at a temperature of 90°C. Zeehuisen (*61*) patented a process in which textile fiber can be produced from flax, hemp, and the like by boiling the material in alkali mixed with an organic solvent for 30 to 45 min. A bleaching operation using peroxide or hypochlorite may be employed after the digestion stage.

Becker (*62*) was awarded a patent for a continuous process for digesting vegetable fibers in which the material along with the cooking liquor is introduced into the top of a tower, heated during descent, and discharged at the bottom. Spencer and Jacobson (*63*) obtained a patent for a process to make paper and board from cotton stalks by cooking the chopped stalks in dilute aqueous sodium hydroxide at about 80°C., gently beating the cooked fibers, and passing them (still in the cooking liquor) to papermaking machinery.

A discussion of the properties of mechanical pulp produced from sawmill waste is presented (*64*). It is pointed out that cold immersion in 5% NaOH increased the strength and reduced the power consumption but caused low whiteness, which could be raised by bleaching with zinc dithionite and sulfur dioxide, but at considerable expense.

Schuerch (*65*) proposes an experimental 2-stage pulping process for separating hemicellulose, cellulose, and hydrogenated lignin from sawdust. The sawdust is pre-extracted with 7 to 12% NaOH at 80 to 100°C. The alkaline liquors are separated and the residual wood meal is pulped by a conventional soda cook. Stewart (*66*) also examined the possibility of using sawdust as a raw material, but in the production of mechanical pulp. Giving the material a cold caustic steeping produced the same results as with sawmill shavings (*64*).

Pessolano (*67*) reports that, if bagasse is chemically depithed using dilute alkali instead of mechanically depithed, the pith can be converted into semichemical pulp by mild digestion in an alkaline medium at atmospheric pressure. The properties of this pulp are similar to those of conventional groundwood. The pulp can be used, in blends with kraft or wastepaper pulps, for the manufacture of corrugated board and packaging papers. Atkinson and Rogers (*68*) obtained a patent for an 8-step process for pulping bagasse in which the third, fifth, and seventh steps are alkaline treatments with sodium hydroxide at 95°C.

Methods for pulping straw, especially the monosulphite, the Celdecor-Pomilio, and the mechanochemical process, are reviewed (*69*), and the characteristics of the resulting straw pulps are compared. Thiriet (*70*) investigated several processes for producing straw pulp including the Phoenix process, DeVains-Aussedat process, and Thiriena process. The Thiriena process (caustic soda and carbonate at atmospheric pressure) is described in detail, including equipment, procedure, consumption and losses of chemicals, and recovery. In conclusion, continuous straw pulping processes and

an installation using a cold modification of the Thiriena process are mentioned.

Dorst (*71*) obtained a Dutch patent for a treatment in which straw is treated with a solution of 1.0 to 8.1% NaOH and 0.3 to 1.2% zinc salt for 1 to 4 hr. A good quality paper is claimed. Sadler, *et al.* (*72*) obtained a patent for a straw treatment using cold sodium hydroxide. After the treatment, the excess hydroxide is squeezed off and the fibrous material washed with water or dilute sodium hydroxide. The material is then pressed and the precipitable substances extracted.

Lauer and Ghoneim (*73*) cooked rice straw for 4 hr. with 3% NaOH at temperatures ranging from 60 to 170°C. Maximum lignin removal and the lowest ash and silica contents were noted at 100°C. Pustelnik and Protekta (*74*) discuss the Aronovsky pulping method and the results of investigations dealing with the application of this method to rye straw of relatively high lignin content. Optimum conditions for producing straw pulps of 60% yield and satisfactory strength properties were established: active alkali 10 to 12%, sulphidity over 15%, cooking temperature 88 to 93°C., and cooking time 30 to 60 min.

Wells (*75*, *76*) obtained patents for producing flax fiber from seed flax by mechanically working the straw into tow or fluff. The tow is then given successive soaking periods totaling 48 to 96 hr. in dilute caustic soda at less than 80°F., beaten to separate the fibers, and washed in conventional papermaking equipment. Fibers so treated are not degraded and after bleaching are suitable for the highest grades of paper.

Ayroud and Jacquemin (*77*) studied the rapid conversion of wheat straw into pulp in a Dyno-Pulper. The best conditions entailed the use of 10 to 12% NaOH for 0.5 hr. at 93°C. Strength tests indicate that the pulp may be used satisfactorily in the manufacture of wrapping paper. Ernst, *et al.* (*78*) carried out an experiment to study the 15-min. pulping of wheat straw at caustic concentrations of 4 to 10% and temperatures of 100 to 180°C. Français (*79*) discusses the manufacture of pulp from wheat straw by the lime process and by the cold caustic process. A satisfactory pulp was obtained by the cold caustic process by macerating for 16 hr. with 2% NaOH. At the end of the steeping period, and prior to washing, the fibers were treated in a kollergang for 20 min. in the presence of black liquor. The physical properties of the pulp resembled those of chemical straw pulps.

PULPING OF WOOD

MacLaurin and Peckham (*80*) report on a study of the semichemical pulping of southern red oak, in which a single cold caustic cook was made. The cold cuastic pulp was weak but light colored. Brown (*81*) reports on the use of batch and continuous cold soda pulping methods to pulp several southern hardwoods including oak, sweetgum, and cottonwood.

Jensen (*82*) reviews the morphological characteristics and chemical composition of birchwood and discusses the production and properties of chemical, high-yield, semichemical, and mechanochemical (cold soda) pulps from birchwood.

Otis (*83*) reports that the Diamond Match Co. is turning out good softwood mechanical pulp using a modified Bauerite process.

Bhat and Virmani (*84*, *85*) treated blue gum groundwood pulp with 2, 3, 4, and 5% NaOH at each of three temperatures: 30, 50, and 70°C. The strength properties improved with increased temperature and caustic concentration, the greatest improvement being achieved with 5% caustic at 70°C. Decreases in pulp weight and brightness during caustic treatment were negligible. Bhat and Gupta (*86*) soaked chips of blue gum in caustic soda solutions of 25, 50, and 75 g. per l. for 2, 4, 8, and 24 hr. at room temperature. The yields were quite high and showed no appreciable difference with increases in concentration or soaking time. Papermaking experiments indicated that pulps obtained from blue gum by the cold soda process are suitable for the manufacture of cheap writing and printing papers.

Bugg and Pearson (*87*) present an outline of the conditions adopted for the cold soda process in the plant at Boyer, Australia. Typical results for strength properties and refining energy are given for a number of wood species, and the performance of the pulp in the newsprint furnish is briefly discussed.

Somerville and Pearson (*88*) report on an experiment carried out on the cold soda pulping of eucalpyt wood. The effects on strength and brightness of the amount of soda absorbed by the chips in a batchwise soaking stage of 2 hr., the freeness of refined pulp, and the temperature of soaking were determined for a range of wood qualities. Conditions suitable for brightening the pulp with hypochlorites, hydrosulfites, and peroxide are described. Watson, *et al.* (*89*, *90*) prepared cold soda pulps from *Eucalyptus regnans* to show the effects of alkali concentration, temperature, and the use of air-dry and water-soaked chips on pulp preparation and paper properties.

Hosaka, *et al.* (*91*) soaked aspen chips in cold sodium hydroxide and studied the effects of soaking time, temperature, and concentration on the properties of the pulps obtained. Colombo, *et al.* (*92*, *93*) describe a modified cold soda process used with aspen chips in which the chips are impregnated for 10 min. with a solution of 40 g. per l. NaOH at 40°C. containing 0.05% of a surface-active agent. The chips are then passed through a series of cylindrical presses at various speeds between which they are soaked and digested in caustic soda for a total time of about 30 min. Fiberization is completed by the use of several disk refiners. The resulting pulp, obtained in 80% yield or better, can be brightened considerably by treatment with 1% SO_2 at pH 5.5 to 6.0 and has good strength, softness, absorption, and drainage properties.

Brown and Hilton (*94*) describe the method for accelerating the penetration of cold soda pulping liquor in which mechanical forces are applied directly to the chips during the alkali treatment. The repeated cycles of compression and decompression provided by the experimental roller press used quickly forced the caustic soda solution into the chips, and after a few minutes produced partially fiberized chip material that was completely treated. Brown and Monsson (*95*) report that the pulp produced was bleached with 11% chlorine in the form of calcium hypochlorite in a single-stage bleach and converted into magazine-book type papers. The effect on papermaking operations of the characteristics of the pulps used, and properties of pulps made by

combination with varying amounts of commercial groundwood furnish are described.

Brown and McGovern (*96*) report on experiments at the U. S. Forest Products Laboratory made in 1950 wherein aspen chips were given mild treatments with sodium hydroxide and then mechanically fiberized to produce pulps in the yield range of 82 to 95%. Pulps obtained were converted into corrugating board that compared favorably with commercial hardwood semichemical board in strength properties.

Ceragioli (*97*) treated poplarwood chips for 5 hr. at 20°C. with solutions containing 10, 25, 40, 55, and 70 g. per l. NaOH to evaluate some process variables. Data on several clones of *Populus euramericana* are presented (*98*). The data include taxonomic characteristics, conditions of growth and utilization, chemical composition, and the properties of soda, semichemical sulfite, and cold soda pulps

McGovern (*99*) discusses some of the processes of the forest products industry which might be useful tools for utilizing hardwoods. The semichemical pulping processes, including the cold soda process, are described as being especially suitable for hardwoods. Brown and McGovern (*100*) report on cold soda pulping studies in which several hardwoods (aspen, birch, red alder, sweet gum, cottonwood, red and white oak) were pulped successfully singly and in mixtures.

Champion (*101*) describes the cold soda pulping process and remarks that although the process is already in commerical use, its possibilities have not yet been completely explored. Also, since the method is applicable to hardwoods, it promises to open the door to one of America's richest and most neglected reserves of raw materials—the farm woodlot stands. These stands comprise over 165,000,000 acres, more than twice the amount owned by industry and more than is owned by government at all levels.

Chidester (*102, 103*) discusses in general the pulping of hardwoods and the suitability of different processes and in particular the utilization of semichemical hardwood pulps in the manufacture of newsprint. The principal effect of developments in this field would be to broaden the base of raw material supplies.

Farber (*104–106*) obtained patents for a series of processes for the digestion of hardwoods. The first consists of a digestion for 1 to 2 hr. at 15 to 30°C. in a 0.4 to 2.5% aq. Na_2SO_3 solution followed by a digestion for 1 to 2 hr. at 70 to 80°C. in a 1 to 4% aq. NaOH solution. The second consists of a digestion at 40°C. in an aqueous solution of 0.5% NaOH and sodium sulphite. The third consists of a digestion at 55 to 75°C. in a solution of 1 to 4% NaOH and 0.4 to 2.5% Na_2SO_3.

Kraft (*107*) reports that in 1955 the American pulp industry filled about 16% of its wood requirements with hardwoods. The author reviews some of the pulping procedures used in connection with hardwoods. Considerable expansion in the use of hardwoods is anticipated. Laviste (*108*) reports that conventional sulfite or kraft pulps can be replaced with different kinds of pulp made of hardwood. The properties of hardwood pulps made by the sulfite, semichemical, and cold soda processes are described.

Pancirolli and Ceragioli (*109*) prepared cold soda and neutral sulfite semichemical pulps from hardwood coppice to study its use in the manufacture of newsprint. The mechanical strength of the pulps was comparable to, or higher than, that of spruce and poplar groundwoods, but their opacity was considerably lower. Newsprint sheets manufactured from a mixture of 15% spruce sulfite pulp, 42.5% spruce groundwood, and 42.5% hardwood coppice semichemical pulp had good mechanical strength properties, but low opacity and printability.

Runket, *et al.* (*110*) treated beechwood under four different conditions of temperature and time with 2.4% NaOH. On the basis of their experiments the authors suggest that hardwood semichemical soda pulps, prepared at relatively low temperatures merit further attention. Seidl (*111*) discusses the various types of processes suitable for pulping hardwoods, including soda, sulfate, semichemical and cold soda processes, and the types of different products for which each pulp is suited.

Vilars (*113*) produced pulps from birch, hornbeam, basswood, aspen, beech, and oak chips by treating them for 4 hr. at 15 to 20°C. with caustic soda solutions. This was followed by grinding for about 0.5 hr. and treatment in a Lamort disintegrator. The properties of the pulps obtained are presented.

Voiret (*114*) describes a modified cold soda process which is suitable for pulping mixtures of small dimensioned hardwoods and which eliminates the costly peroxide bleaching. It consists of omitting the fiberization step and limiting the quantity of sodium hydroxide absorbed by the chips to 4%, so that the pH inside the chips does not exceed 11 after a few hours of impregnation.

THE ACTION OF ALKALI

Klauditz (*115*) studied the effect of acetyl groups on the tensile strength of hardwoods. When green birchwood or aspenwood was treated at 20°C. with 0.2% NaOH solution, most of the original acetyl groups were removed, and the so-called "biological" tensile strength decreased to 50 to 60% of that of the untreated wood. This is attributed to the removal of acetyl groups from the polyuronides of the hemicellulose along with a weakening of the bond between hemicellulose and lignin.

Enkvist, *et al.* (*116*) report that laboratory digestions of pinewood with sodium hydroxide solutions containing various reducing agents did not show any advantage of the reducing agents, compared with the effect of sulfides normally used in sulfate pulping. Comparative soda and sulfate digestions of sprucewood sawdust indicated that pretreatment with 4% NaOH at room temperature does not markedly alter the solubility of the dissolved lignin in organic solvents.

Stewart (*117*) subjected the wood substance and modified wood substance of *Eucalyptus regnans* to various hydrolytic treatments including dilute aqueous solutions of sodium hydroxide at room temperature. The results are briefly reviewed and discussed.

Prey, *et al.* (*118*) present the results of an investigation of the claim of Brauns and Grimes which states that the alkali consumption for a normal one-stage soda cook amounts to approximately 16%, 75% of which is consumed by the hemicelluloses. The results of the present investigations showed that only a quarter of the 12% of alkali is required for dissolving the hemi-

celluloses, whereas the remaining three quarters are used for neutralizing the acids formed. The degradation of hemicelluloses can only be prevented by the use of temperatures below 100°C. and pH values below 12.

Macmillan, *et al.* (*119*) studied the action of caustic soda on jute. The first extraction eliminated the major portion of soluble constituents, whereas subsequent treatments had relatively small effects. A small portion of lignin is solubilized even after a mild treatment; the hexosan fraction remains practically unaffected by the action of cold caustic soda. The shrinkage suffered by jute in concentrated caustic soda is enhanced with increased concentration and decreased temperature. A marked decrease in the dry strength of the yarn occurs after a treatment with concentrated alkali at room temperature.

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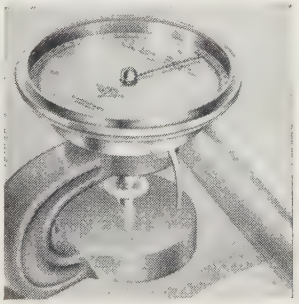

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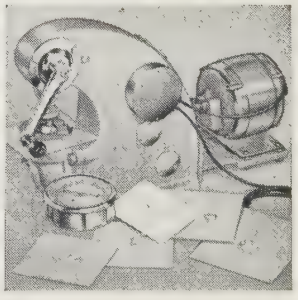

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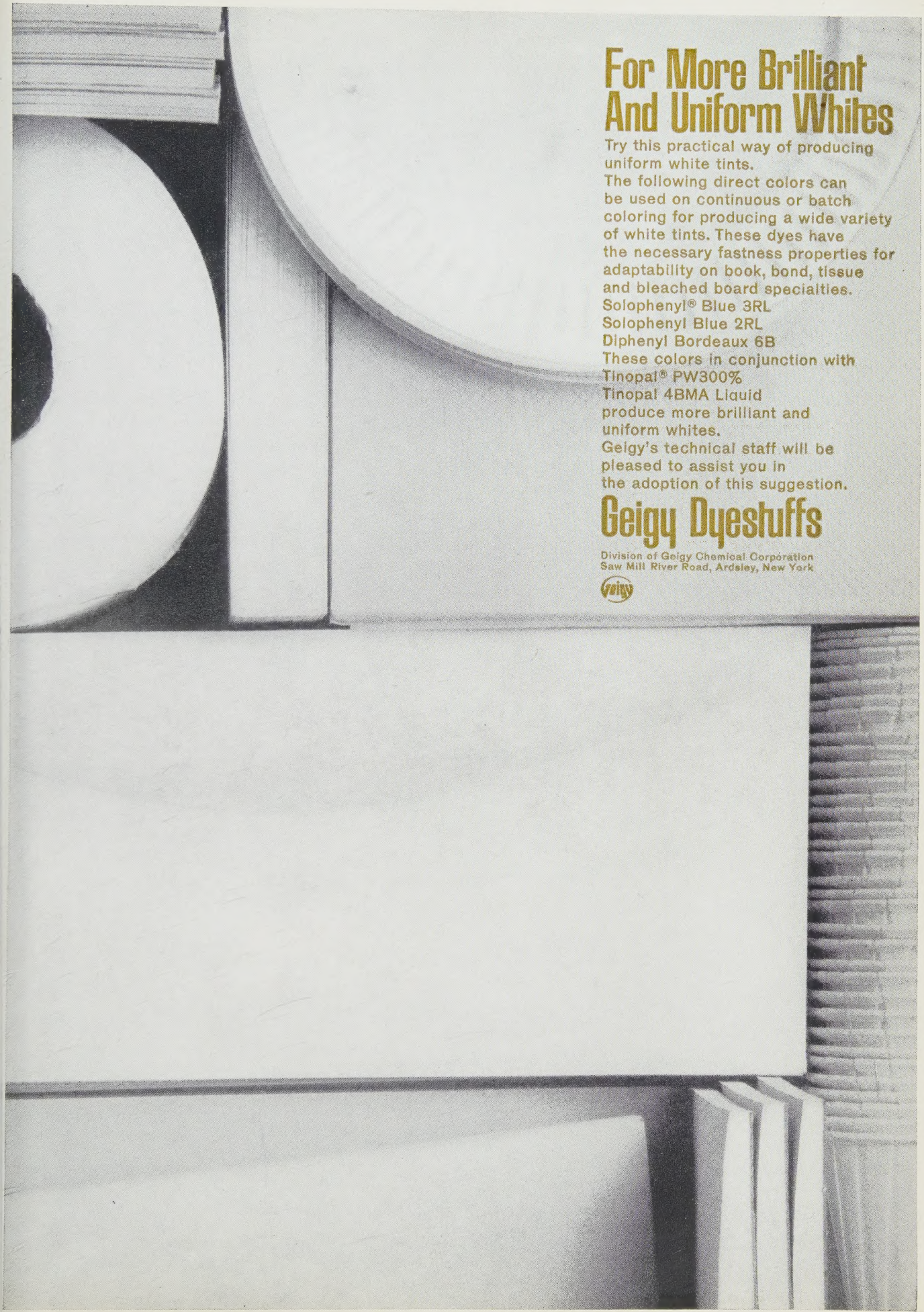

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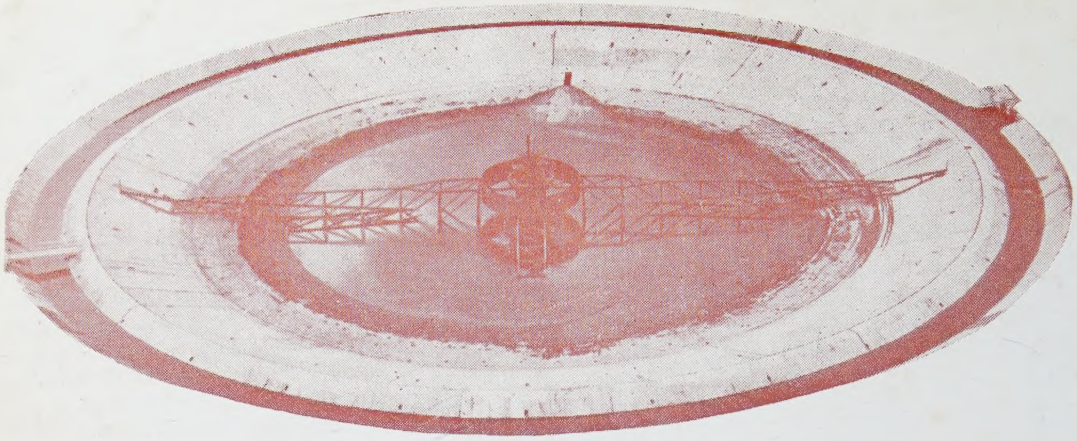

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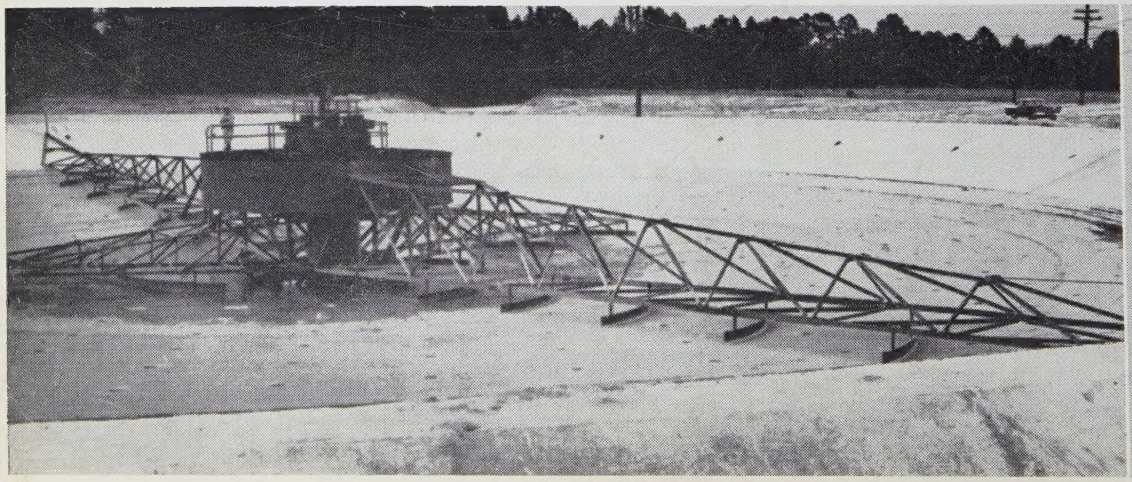

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